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Using Transformative Learning Theory to Investigate Ways to Enrich University Teaching: Focus on the Implementation of Student-Centered Teaching in Large Introductory Science Courses

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To the Graduate Council:

I am submitting herewith a dissertation written by Ioana Alexandra Badara entitled "Using Transformative Learning Theory to Investigate Ways to Enrich University Teaching: Focus on the Implementation of Student-Centered Teaching in Large Introductory Science Courses." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

Rita A. Hagevik, Major Professor

We have read this dissertation and recommend its acceptance:

Ralph Brockett, Gary Skolits, Gina Barclay-MacLaughlin

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Dr. Gary Skolits

Accepted for the Council:

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Carolyn R. Hodges
Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

Using Transformative Learning Theory to Investigate Ways to Enrich University Teaching: Focus on the Implementation of Student-Centered Teaching in Large Science Courses

A Dissertation Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Ioana Alexandra Badara
May 2011

DEDICATION

My son, John Paul, has grown up through my years in graduate school. He has inspired me and kept me strong. John Paul really has been the ultimate reason for me to move ahead and seek answers. This endeavor was born with him and I hope I can make him as proud as he has made me.

My husband, Mircea, was unceasing in his patience and held steadfast in his belief in my abilities. He has been supportive of my work and has shared the many uncertainties, challenges and sacrifices for completing this dissertation.

My father taught me to go to the top and never give up. He taught me how to ask questions and pursue answers. He gave me the love for everyday learning. He once told me: “If you feel you have nothing to learn one day, start learning a poem and then recite it to someone else.” I feel proud for half of who I am comes from him.

This dissertation is dedicated to my son, husband, and to the memory of my father.

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I am thankful for my mentors who pointed me in the right direction. Your thoughtful comments on this dissertation have made the process a wonderful learning experience. In particular, I would like to thank my chair, Dr. Rita Hagevik, who has given me guidance throughout this process and faithfully walked beside rather than in front of me on my path of development. Her ability to identify the weaknesses in my research and suggest possible routes to take has helped me improve my scholarly production. She has also provided me with numerous opportunities to learn about what it means to be a science teacher educator, including writing research articles, presenting at local and national conferences, and conducting research. For all those opportunities I am most grateful. I would also like to thank the other members of my committee, Dr. Ralph Brockett and Dr. Gary Skolits, whose constructive comments and guidance were truly appreciated. I am also thankful for the insightful remarks that Dr. Gina Barclay-Mclaughlin had regarding the interview process.

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Last but not least, I would like to thank all my students who were an important source of inspiration, motivation and strength. You taught me what no other teacher did!

ABSTRACT

Previous studies have reported high attrition rates in large-enrollment science courses where teacher-centered instruction was prevalent. The scientific literature provides strong evidence that student-centered teaching, which involves extensive active learning, leads to deepened learning as the result of effective student engagement. Consequently, professional development initiatives have continually focused on assisting academics with the implementation of active learning. Generally, higher education institutions engage faculty in professional development through in-service workshops that facilitate learning new teaching techniques in a specific context. These workshops usually do not include self-scrutiny concerning teaching or do they provide continuous support for the implementation of strategies learned in the workshop.

The purpose of this study was to explore the influence of a professional development program that consisted of a workshop focused on the implementation of active learning in large science courses and extended to include post-workshop activities, on participants' enactment of teaching practices introduced in the workshop. More specifically, through a qualitative methodology and employing transformative learning theory, this work evaluated the influence of science instructors' engagement in dialogue and critical self-reflection on their teaching approaches and practices. Engagement in critical reflection was facilitated through watching of teaching videotapes followed by participants' engagement in dialogue about teaching with the researcher. Findings suggest that providing continuous post-workshop support by fostering engagement in critical self-reflection and dialogue, can lead to transformative learning about teaching. More specifically, participation in the program led to the transformation of teaching practices, while teaching approaches remained unchanged. While some obstacles to the transformation of teaching approaches were identified, major outcomes indicate that meaningful professional development can go far beyond learning how to use new teaching strategies through faculty engagement in critical reflection and dialogue on teaching.

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CHAPTER I
INTRODUCTION

At large research universities, large-enrollment introductory science courses are part of the general education requirements. The student population enrolled in these large courses is mixed: students who intend to pursue a science-related major and who have strong science backgrounds blend with undecided students and students that pursue non-science related majors. In addition to these introductory courses, many upper level science courses are also large-enrollment courses. Throughout this work, a large-enrollment course was defined as one in which 100 students or more are enrolled (Chism, 1989).

Very importantly, the literature on large courses (Baldwin, 2009; Bok, 2006; Eagan and Jaeger, 2008; Seymour and Hewitt, 1997; Tobias, 1990) has reported high attrition rates in large-enrollment science courses where the main instructional method has traditionally been lecture. The National Research Council (NRC) Committee on Undergraduate Science Education has long questioned, "why introductory science courses in many colleges and universities still rely primarily on lectures […] where students memorize facts and concepts, but have little opportunity for reflection, discussion, or testing of ideas" (NRC, 2003, p. 1). This suggests that this teaching approach 1) may fail to motivate meaningful intellectual engagement, 2) may not promote conceptual understanding, and 3) may not provide significant relevance between theory and real life to today's college students.

As part of the retention efforts initiated at a large public University, a Teaching and Learning Center was created in the spring of 2009. Its main goal was to provide assistance to faculty members in developing current and effective teaching skills. Immediately after its establishment, one of the initiatives developed by this center included the organization of a two-day workshop aimed at enriching teaching practices of science instructors who taught large-enrollment courses. The final goal of this workshop was to assist faculty of large science classes in learning ways to promote better student

engagement, deepen students' learning of science, and to lower attrition rates in their classes.

The overall learning objectives of the workshop were that participants gained a better understanding of the characteristics and motivations of the students they taught, knowledge of their students' various learning styles, knowledge of verbal and non-verbal presentation skills employed when teaching large classes, knowledge of student-centered teaching approaches successful in large lecture sections, enhanced abilities to engage students in their learning process within these large lecture sections, and skills necessary to undertake the redesign of a large-enrollment science course for the incorporation of student-centered teaching strategies. More specifically, the workshop aimed at facilitating participants' understanding and implementation of student-centered teaching methods that were reported in the literature to be effective in promoting increased student engagement and deep approaches to student learning.

The National Research Council (NRC, 1996) argues that the development of expert science teachers requires ample opportunities for reflection. Moreover, the National Science Teachers Association (NSTA) encourages professional development for science teachers and offers a multitude of research-based guidelines for designing and implementing professional development for these practicing teachers. For instance, NSTA proposes that professional development programs should engage science educators in transformative learning experiences that confront deeply held beliefs, knowledge, and habits of practice, and should actively involve teachers in observing, analyzing, and applying feedback to teaching practices (NSTA, 2006). These recommendations were infused into a professional development program, which comprised the abovementioned workshop, and involved science instructors who taught large-enrollment courses. Participants in this program were the focus of the study.

Problem Statement

Most professional development actions initiated by centers of teaching and learning in colleges and universities nationwide are aimed at enriching teaching practices employed by college faculty but limit themselves to facilitating learning about and application of a certain new teaching technique in a specific context. In general, these professional development initiatives consist of workshops that do not extend beyond workshop participation to initiate self-scrutiny concerning teaching or to provide continuous assistance and support for the implementation of strategies learned in the workshop. However, meaningful professional development must go far beyond learning how to use a new teaching strategy for increasing student engagement. It must involve educators as whole persons and include their values, beliefs and assumptions about teaching, participating in transformative learning that leads to individuation (Cranton and King, 2003).

Purpose of the study

The purpose of this study was to explore a professional development program that consisted of a workshop and included post-workshop activities initiated by professional developers with the intention to increase interaction between them and college faculty, facilitate self-reflection about teaching, and provide continuous support for participants' enactment of teaching practices introduced in the workshop.

As initially defined by Rice (1991), scholarly teaching comprises three important elements: academic content knowledge (synoptic capacity), pedagogical content knowledge, and knowledge about student learning. By virtue of the fact that study participants were science academics continuously engaged in scientific research, they possessed expert knowledge of their content areas. Hence, this study evaluated the

influence of the professional development program on participants' development of scholarly teaching.

Research Questions

The research questions that guided this study were:

1) What are participants' conceptions about teaching large science courses?
2) How do participants' teaching approaches transform after engaging in reflection and dialogue on their teaching?
3) To what extent are these transformations reflected in their teaching practices?

Significance of the Study

A review of research examining professional development of science instructors in higher education shows very few studies have investigated initiatives for the teaching enrichment of these teachers. Many questions are still unanswered regarding the effectiveness of professional development programs that target science instructors. For instance, no studies employed the transformative learning theory as a lens for the exploration of learning how to teach by university science instructors. Little is known about the transformation of teaching conceptions, approaches, and practices of science instructors toward student-centered teaching, whereas no existing study explored all these issues in the context of teaching large-enrollment science courses. Information obtained from this study was important in providing input and direction for the organization of future professional development programs intended to facilitate the transformation of participants' approaches to teaching large-enrollment science courses and the implementation of student-centered teaching in these courses. This study is also critical to

understanding how a combination between a workshop and constant, long-term interactions between university science instructors and one professional developer may influence scholarly science teaching. These interactions were represented by participants' engagement in reflection and dialogue with the researcher about teaching large science courses during the reflective cycles. Moreover, this study showed how participants' simultaneous engagement in the scholarship of discovery, their teaching experience, and teaching orientation (student-centered vs. teacher-centered) may influence the development of scholarly teaching.

Research Design

Background

The theoretical underpinnings of the present study are represented by transformative learning theory (Mezirow, 1978, 1981, 1990, 1991, 2000, 2009). The theory maintains that transformative learning about teaching takes place through constant questioning of teaching approaches, or critical self-reflection, and through engagement in discussion with others, or discourse, both leading to the acquisition of alternative ways of understanding teaching. Based on the tenets of transformative learning theory applied in the context of professional development in higher education, Kreber and Cranton (2000) elaborated a model of the development of scholarship of teaching and learning in the academe. Their model argues that significant professional development programs for higher education faculty extend their focus beyond the transmission of knowledge about a certain educational concept or teaching strategy by fostering critical self-reflection on teaching, which leads to a better understanding of teaching and learning, and finally to changes in the practices of teaching.

This study investigated science instructors' conceptions about and approaches to teaching large science courses through their participation in a professional development program. This program encompassed a workshop followed by post-workshop interactions

between the researcher and program participants. The post-workshop interactions were intended to facilitate participants' engagement in reflection and dialogue about teaching as ways to promote transformative learning about student-centered teaching. The investigative approach employed by this research is represented by multiple case study methodology. Case study methodology was selected because it generally recognizes the importance of context, focuses on the elucidation of conceptions, and enables in-depth examination of a contemporary phenomenon within its real-life context. Individual cases were represented by three university science instructors involved in the program.

Program Description

The design of the professional development program was based entirely on transformative learning theory. The program extended over one academic year and consisted of a two-day workshop followed by participants' engagement in reflection cycles. The reflection cycles were initiated by participants' watching their videotaped teaching, which provided opportunities to reflect upon their teaching practice, including instructional strategies and levels of student engagement, to identify meaningful goals for instructional improvement, and to develop action plans for the implementation of more student-centered teaching strategies learned in the workshop (Lebak and Tinsley, 2010). Thus, each new video was intended to begin another reflection cycle leading to participants' engagement in reflection and dialogue with the researcher about their teaching beliefs and practices.

Description of Participants

Three science instructors agreed to participate in this study and each of them represented one case. They were recruited from the participants in the workshop. None of the study participants had had any formal teaching training and all of them taught a large-enrollment science courses for at least one semester during their participation in the program.

Adrian was an Anthropology professor who had been teaching for approximately 20 years and had 13 years of experience teaching the same introductory large class. He

was a male in his early fifties. Adrian had been at his University for approximately 19 years and a Department Head for 3 years. He was not actively involved in research in his field and did not direct student research. His academic involvement included teaching undergraduate and graduate courses, and performing administrative work in his department.

John was a Chemistry professor who, at the time of entry into the program, had never taught a large course. John was a male in his mid-forties. He had 15 years of teaching experience gained since he joined his University. John was also involved in administrative work, being the Associate Dean for Teaching and Diversity and Director of Graduate Studies in his College. He was the leader of a large research laboratory where he directed student research. John's academic duties were divided among research, teaching, and administrative roles.

Siobhan was an assistant professor of Physics who had been on the tenure track for 3 years, since she joined her University. Siobhan was a British female in her mid-thirties. She had 2 years of teaching experience, from which her experience in teaching a large-enrollment class spanned two semesters. She was actively involved in research, also directing student research in her laboratory. Siobhan's academic duties were divided among research, teaching, and academic service for her University.

Method and Procedures

This study can be best described as a participant observation multiple case study. Study participants had the opportunity to interact with the researcher prior to and during the workshop. The researcher assumed a pivotal role in the organization of the program and played an active role as one of the teaching and learning center facilitators of the workshop. During the post-workshop part of the program, the researcher constantly maintained close interaction with study participants through her participation in the reflective cycles. During the reflective cycles triggered by watching videos of their

teaching, the researcher engaged in discussions with the participants regarding their teaching behaviors, and offered support for the implementation of student-centered strategies. Thus, the researcher had an active role in maintaining the engagement of study participants in reflective cycles and overall, her role was perceived by the participants to be that of a representative for the Teaching and Learning Center.

In order to follow participants' transformations of teaching conceptions, approaches, and practices throughout the program, the study was divided into three stages: 1) the pre-program stage, 2) the program stage, and 3) the post-program stage. Throughout the study, the researcher maintained a research journal in which she recorded field notes during and after her encounters with each participant in the study. During the first phase of the study, the researcher met with each participant to discuss their perceptions of their roles as instructors of large-enrollment courses, their past teaching experiences, and to ask them what they would like to learn in the workshop. At this time, participants were asked to provide a one-page reflection on teaching large courses, a statement of teaching philosophy, and syllabi for their large courses. Information from these sources and from the researcher's notes supported the evaluation of participants' beliefs and teaching practices prior to attending the program, and hence provided information for the first two research questions. The data collected during this stage were considered free of bias from participants' involvement in the program.

During the second stage of the study, before any reflective cycle was initiated or new student-centered teaching strategies were implemented by the participants, a semi-structured interview was conducted with each participant. Questions included in this interview explored participants' conceptions about teaching large courses, such as their considerations about course relevance, structure, pedagogy, assessment, students' prior knowledge, and ways to facilitate student-student and student-teacher interactions in their large courses. Additionally, at least three teaching sessions were videotaped by the researcher within each case, during the course of this stage. The purpose of video recording these course sessions was twofold: 1) to serve as triggers for the reflective cycles and therefore provide an opportunity for participants to reflect on their own teaching and engage in dialogue with the researcher, and 2) for videotapes to be used as

data sources for the analysis of participants' teaching practices throughout the program. Following suggestions of scholars in the field (Wilson and Berne, 1999), observation and interviews were considered appropriate methods for capturing in-depth and nuanced constructs, such as critical reflection, and for answering research questions that investigated the process of change of teaching approaches or practices. Furthermore, the teaching videotapes were evaluated by the researcher in terms of the extent to which participants incorporated student-centered, active learning practices into their teaching. For this purpose, the Reformed Teaching Observation Protocol (RTOP) was employed. This is an observational instrument designed to evaluate science instruction in college science classrooms (Lawson et al., 2002; Sawada et al., 2000). To facilitate triangulation of the information, researcher's notes taken during meetings with participants were corroborated with course documents provided by participants, such as syllabi and teaching artifacts.

In the last stage of the study, a final open-ended interview was conducted in order to determine whether participants changed their teaching approaches as a result of their participation in the program. The final interview contained similar questions to the ones included in the initial interview and additional items aimed to investigate participants' opinions about the program in general, and more specifically, about their engagement in reflection and dialogue about teaching during the reflective cycles. A comparison between participants' answers to questions in the first and final interviews revealed participants' changes in approaches to teaching as a result of becoming engaged in reflection and dialogue..

During data analysis for each case study, the interviews, videotaped course sessions, field notes, statements of teaching philosophy, and reflections formed the basis for the development of categories and themes. After performing two cycles of coding and creating the final codes, the existence of patterns among codes was examined, and related codes were included into same categories. Each category was examined for internal consistency and distinctness from other categories. After all categories were refined, the major themes were identified by exploring the relationships across categories. This process of coding, categorizing, and developing themes was repeated for each unit and

set of data. Finally, the integration of data into themes yielded an understanding of each case studied. For each case, transformations of participants' teaching practices were evaluated through a comparison of the RTOP scores from each videotaped teaching session. Thus, an increase of the RTOP scores from the beginning toward the end of participation in the program was considered an indicator of an increased use of student-centered teaching methods. Nevertheless, interpretation of RTOP scores was performed in the large context of each case, and corroborated with information from other data sources. Finally, the within-case analysis was followed by the cross-case analysis. Findings were aggregated across the three case studies by examining common relationships among the categories and themes emerged from each case.

Assumptions

The following assumptions underlie this study:

1) The researcher assumed that, when provided with the teaching videotapes, all participants would engage in reflection and dialogue about their teaching;

2) Once engaged in the reflective cycles, the researcher assumed that participants would question their teaching in such ways as to lead to the transformation of their teaching approaches and practices.

Limitations

The following limitations underlie this study:

1) Participants agreed to participate in the study and as such, may have had certain dispositions;

2) The researcher assumed the role of a participant observer. Thus, some situations may have been created due to the investigator's active participation in the study.

Organization

This dissertation is organized into five chapters. The first chapter provides the introduction to the study, statement of the problem, statement of the purpose, research design of the study, assumptions and limitations of the study, significance of the study, and the definitions of key terms. In the second chapter a review of the literature and the theoretical framework are presented. In the third chapter the research methodology describes the study design, the context of the study, the study participants, the data sources and the data collection procedures, followed by the data analysis processes. The fourth chapter offers the research findings and includes the three case studies. A cross case analysis of the emergent themes concludes the chapter. These findings inform the final chapter which draws conclusions and outlines implications for future research and practice.

Definition of Key Terms

The following is a list of terms employed in this study and their definitions. The purpose of this list is to clarify the application of these terms by the author to the context of this study. These include:

Active learning - when used with regard to students, it involves active construction of knowledge during social interaction with peers and the instructor (Johnson, Johnson and Smith, 1998). When used with regard to teachers, it refers to student-centered teaching approaches that involve students working individually or in groups on tasks related to the course objectives;

Program - two-day workshop followed by participation in reflective cycles triggered by watching of teaching videotapes;

Reflective cycles - stimulated by watching of teaching videotapes, and represented by individual encounters between the researcher and individual participants subsequent to

participants' self-analysis of videotaped course sessions. They are intended to promote analysis and critical self-reflection about teaching by leading to participants' engagement in discussions about their teaching practices (Lebak and Tinsley, 2010);

Scholarship of teaching (SoT) - engagement with the existing knowledge on teaching and learning, self-reflection on teaching and learning in the academic's discipline, and public sharing of ideas about teaching and learning within the discipline (Martin, Benjamin, Prosser, and Trigwell, 1999); it is used interchangeably with scholarship of teaching and learning (SoTL);

Scientific teaching - the movement of scholarship of teaching and learning in science education in colleges and universities (Handelsman et al., 2004);

Transformative learning – learning theory that views learners engaged in the process of reassessing their worldviews and subsequently changed by the learning experience (Mezirow, 1978, 1981, 1990, 1991, 2000);

Workshop - two-day workshop offered by the center of teaching and learning in the summer of 2009 (see Appendix A for an outline).

CHAPTER II
LITERATURE REVIEW

Shulman (2002) stated that "learning begins with student engagement" (p. 37). Yet, despite this knowledge, large introductory college science courses are common occurrences in Universities, especially during the first two years of college. Professional developers are working to assist instructors in these courses with implementing student-centered approaches or strategies. Student-centered teaching methods are those that engage students in active learning. These strategies have been shown to promote students' deep approaches to learning, which facilitate the development of higher order cognitive processes, and hence, the understanding and applicability of scientific concepts (Appleton, 1997; Bransford, Brown and Cocking,1999; Michael and Modell, 2003).

This chapter synthesizes a review of the literature related to professional development strategies employed in higher education for the purpose of promoting student-centered teaching and includes the following sections:

1) Theoretical framework;
2) The SoTL movement;
3) Professional development in higher education;
4) Teaching and learning approaches;
5) Summary.

Theoretical Framework

The theoretical underpinnings of the present study are represented by Mezirow's transformative learning theory, a well-established theory in adult education. Based on a study of eighty-three women returning to college, Mezirow first framed his theory as perspective transformation (1975, 1978, 1981), acknowledging reflection as one of the most important components of learning in adulthood because it enabled people to

recognize, reassess, and modify structures of assumptions and expectations that scaffold their points of view and influence their thinking, beliefs, attitudes, and actions. Over the last three decades, Mezirow has continued to refine this theory (1990, 1991, 2000, 2009) and now an extensive literature on this theory exists, and as dissemination vehicles, a peer-reviewed journal (Journal of Transformative Education) and an International Transformative Learning Conference. Both focus on educational practices informed by the transformative learning theory. Ever since its formulation, a multitude of research studies have continued to provide insights into this theory. This section describes the core concepts of transformative learning theory, concentrating on reflection and dialogue as its major constituents, followed by the model of the scholarship of teaching (SoTL) (Kreber and Cranton, 2000) applied to higher education.

Mezirow's theory is deeply rooted in Habermas's (1971) theory of knowledge-constitutive interests, which argues that there are three basic human interests: in controlling nature, in reaching social agreement, and in promoting individual growth, from which empirical, communicative and emancipatory knowledge derive. For Habermas, each interest originates in its corresponding approaches to enhancing human survival. Paralleling Habermas's theory, Mezirow distinguishes three different forms of learning, which he labels instrumental, communicative and emancipatory. Instrumental learning is based on the hypothetico-deductive method and hence, it involves controlling the environment or the participating individuals, whereby beliefs are validated by empirical testing to ascertain the accuracy of a hypothesis. For example, teachers are engaged in instrumental learning when they can predict learning events based on research or their teaching experience. However, when faculty learn how to teach, they encounter situations that cannot be overcome through instrumental rationality alone, and they have to rely on the other two approaches to learning. Communicative learning relies on understanding what others mean when they communicate with us and it involves validation of beliefs through reaching consensus within a community. Interacting with others and arriving at a common understanding is based on social and moral norms. Through this lens, learning about teaching is not seen as being subjective within a certain social context, but it is viewed to occur through communication with learners and peers,

and by understanding learners and learning to interact with them. In emancipatory learning, "knowledge is gained through critical self-reflection" (Mezirow, 1991, p. 87) and its purpose is to overcome the limitations of self-knowledge and the social constraints on one's actions and thoughts, thereby leading to self-empowerment. When teachers critically question why they do what they do, they construct emancipatory knowledge. Mezirow equates emancipatory learning with perspective transformation and argues that it is not a separate domain, but it is applicable to both instrumental and communicative processes (Mezirow, 1989).

Transformative learning is predicated on the idea that learners exposed to this type of teaching are seriously challenged to reassess their worldviews and subsequently are changed by this experience. As such, transformative learning is envisioned as teaching for change. Mezirow (2000, p. 19) argues that "learning occurs in four ways: by elaborating existing frames of reference, by learning new frames of reference, by transforming points of view, or by transforming habits of mind". He explains that a frame of reference is a "meaning perspective" that has cognitive, affective and conative dimensions, the sum of assumptions and expectations through which we interpret our experiences and that offers the context for meaning making. A frame of reference is composed of a habit of mind expressed through its resulting point of view. A habit of mind is defined as a set of assumptions (sociolinguistic, moral-ethical, epistemic, philosophical, psychological and aesthetic) about what can be known and through which we make meaning of experiences. Finally, Mezirow defines transformative learning as "learning that transforms problematic frames of reference to make them more inclusive, discriminating, reflective, open, and emotionally able to change" (2009, p. 22).

Transformative learning theory is based on constructivist worldviews, which advance the idea that personal meaning is constructed and/or developed from personal experience and validated through interaction and communication with others. Learning occurs through objective or subjective reframing, where objective reframing involves critical reflection on others' assumptions, and subjective reframing entails critical self-reflection of one's own assumptions (Mezirow, 2000). These reframing processes initially are triggered by a disorienting dilemma and go along the following phases: 1)

self-examination, 2) critical assessment of assumptions, 3) recognition of discontent, 4) exploration of options for new roles, relationships, or actions, 5) planning a course of action, 6) acquiring knowledge and skills for implementing a course of action, 7) provisional trying of new roles, 8) building competence and self-confidence in new roles, relationships, and actions, and 9) reintegration into one's life on the basis of conditions dictated by one's perspective (Mezirow, 2000, p. 22).

Transformative learning is a theory in progress. Despite that the emergence of its critical elements continues to occur from empirical studies and literature reviews, it is essential for the purpose of the present study to describe the core ingredients that frame transformative learning so far. While critical reflection was initially seen as the predominant approach to transformative learning (Mezirow, 1978, 1981, 1990, 1991, 2000), recent research has demonstrated the contribution of other factors and has shown their interconnectedness. Based on the existing literature on transformative learning theory, Taylor (2009, p. 4-14) argues that its critical elements are: promotion of critical reflection, engagement in dialogue, individual experience, holistic orientation of teaching, awareness of context, endorsement of authentic relationships with learners, and learner-centered teaching.

For instance, learners' individual experience provides the medium for the development of discourse leading to critical examination of assumptions – reflection is anchored in experience and is a necessary, but not sufficient, vehicle that turns experience into learning (Cragg, Plotnikoff, Hugo and Casey, 2001; Hamza, 2010; MacLeod, Parkin, Pullon and Robertson, 2003; McAlpine and Weston, 2000). Recent research suggests that a holistic approach to teaching that involves affective and relational ways of knowing, such as engagement of learners with the arts (Butterwick and Lipson-Lawrence, 2009; Dirkx, 2006; Patterson, 2002; Yorks and Kasl, 2006), can act as a trigger for reflective processes and provide an opportunity for engagement in dialogue. Moreover, teachers' awareness of learners' prior experiences and socio-cultural factors that influence the process of learning prove to create a fertile ground for the promotion of perspective transformation (Dirkx and Smith, 2009; Kiely, 2005; Onsando and Billett, 2009). Additionally, several research studies confirm the development of meaningful

relationships with learners as another critical element of the foundation for transformative learning (Cranton, 2006a; Kreber, 2010; Stein, Isaacs and Andrews, 2004), based on the five-facet model of teacher authenticity (Cranton and Carusetta, 2004). From their longitudinal study of twenty-two educators, Cranton and Carusetta (2004) suggested that teacher authenticity involves: 1) self-awareness, 2) awareness of learners' needs and interests compared to those of the educator, 3) openness with others, 4) awareness of how context shapes teaching practice, and 5) engagement in critical reflection and self-reflection about teaching. Last but not least, the conceptual literature mentions learner-centered teaching as central to fostering transformative learning (Cranton, 2006b; Mezirow, 2000; Taylor, 2008), but the research literature fails to explore its challenges and implications for practice (Taylor, 2009).

Despite the wide acceptance of Mezirow's conception of transformative learning (1978, 1981, 1990, 1991, 2000, 2009), there are a variety of alternative views of transformative learning theory that focus on aspects originally overlooked by Mezirow. For instance, a psychoanalytic view of transformative learning associates it with a process of individuation which involves a sense of empowerment, a deeper understanding of one's inner self, and a greater sense of self-responsibility (Cranton, 2000; Dirkx, 2000). A psycho-developmental view of transformative learning centers on continuous reflection leading to incremental, progressive growth, and includes an appreciation for the role of relationships, personal contextual influences, and holistic ways of knowing (Daloz, 1986; Kegan, 1982). A social-emancipatory view, rooted in the work of Freire (1970), equates transformative learning with social transformation, in which individuals constantly reflect and act on the transformation of their world so it can become a more equitable place for all to live. Additionally, other views have recently emerged in the field. For example, the neurobiological perspective of transformative learning suggests that the brain structure changes during the learning process (Janik, 2005). The cultural-spiritual view appreciates a culturally relevant and spiritually grounded approach to transformative pedagogy (Brooks, 2000; Tisdell, 2003). Finally, the planetary view considers that the goal of transformative education is the reorganization of the whole

system (O'Sullivan, 1999). All these alternative conceptions of transformative learning theory were not employed in this study.

The Role of Reflection

The word 'reflection' originates from the Latin verb *reflectere*, which means to bend backwards, and as such, the term was initially introduced in optics to describe reflection of light against a smooth surface. However, in human context, the term is used metaphorically and is intended as thinking and self-understanding (Bengtsson, 1995, 2003). Over the years, varied definitions and descriptions of reflection have been proposed in the fields of philosophy, adult education, and educational psychology. Initially, Kant used a transcendental approach to defining knowledge, and Descartes used a rationalistic approach to define certainty as that which can resist doubt, concluding "*cogito ergo sum*", i.e. I think hence I am. More recently, in *How We Think*, Dewey (1910, 1933) defined reflective thought as the "active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it, and the further conclusions to which it tends" (Dewey, 1910, p. 6). While it is known that Dewey wrote two versions of *How We Think*, one in 1910 and one in 1933, scholars that studied Dewey argue that the 1933 version reveals his shift from nominalism to realism (McCarthy and Sears, 2000; Prawat, 2000). As he explained in the more recent version of the book (Dewey, 1933), reflective thought has its origins in the scientific method, thereby including strict steps: observation of an experience, analysis of experience followed by generation of explanations and development of theories, and culminates with experimentation – a test of the theory. Experimentation in the context of interactions with the environment and the community hence serves as new experience, a platform for learning continuity. As such, Dewey viewed reflection as a forward-moving spiral from practice to theory and back, suggesting that reflection is a vehicle used in the transformation of raw experience into meaning-filled theory grounded in experience, informed by existing theory, and serving the growth of the individual and society (Rodgers, 2002).

The value of reflection in helping professionals learn about and improve their practices was also highlighted by Schön (1987, 1983), who proposed that reflection can be continuous and synchronous with teaching (concurrent reflection-in-action), or it may occur asynchronously at some point after teaching (retrospective reflection-on-action). On the other hand, Brookfield (1995) suggested that one's teaching can be viewed through four lenses: 1) his/her autobiography as teacher and learner, 2) his/her students' critical opinions, 3) his/her peers' critical views, and 4) by accessing theoretical literature on teaching. All these lenses dominated by critical reflection are bolstered by three common assumptions: paradigmatic assumptions that structure the world in fundamental categories, prescriptive assumptions about what one thinks it should happen in a certain situation, and causal assumptions about how the world works and how it can be changed (Brookfield, 1995). Others have suggested that reflection could operate in different arenas. As such, McAlpine and Weston (2000) proposed that practical reflection focused on improving teaching actions in a particular class, while strategic reflection focused on generalized knowledge or approaches to teaching applicable across varied contexts, and epistemic reflection revealed a cognitive awareness of one's reflective processes and how they interfered with teaching.

Returning to the theoretical framework of this study, Mezirow (1975, 1978, 1981, 1990) originally acknowledged critical reflection as the core element of transformative learning. In this content of reflection, it is important to mention the existence of two main theoretical orientations to the original transformative learning developed by Mezirow. The first orientation, initially formulated by Mezirow and espoused by other scholars (Cranton, 2006b; Kegan, 1982), emphasizes personal transformation and growth, in which critical reflection refers to self-critique and leads to greater personal perception in relationship to others. The second orientation, shared by Freire (1970) for example, links individual and social change and perceives reflection as ideological critique leading to the development of learners' awareness of power and agency. The present study employs Mezirow's point of reference with regard to reflection as a vehicle for transformative learning: perspective transformation occurs "through reflection and critique of specific presuppositions upon which a distorted or incomplete meaning perspective is based and

then transforming that perspective through a reorganization of meaning" (Mezirow, 1991, p. 94).

Mezirow (1991, 1990) initially distinguished three kinds of reflections labeled content reflection, process reflection and premise reflection, though he recently ceased to emphasize the distinction among them (Mezirow, 2009). For instance, content reflection refers to reflection on a problem ("what do I know?") without attending to the justification of our beliefs and interpretations of the problem, and process reflection scrutinizes the method of problem solving ("how do I know if it works?"). Content and process reflections may lead to transformation of beliefs, but it is the premise reflection that leads learners' transformations of habits of mind (Mezirow, 1991, 2000; Taylor, 2000). Premise reflection questions the presuppositions underlying the problem solving process ("why does it matter that I attend to this problem?") and, while all reflection involves an element of critique, is synonymous to the term "critical reflection" (Mezirow, 1990, p. 12-13). Mezirow (1990) argues indisputably that the most significant learning experiences in adulthood involve critical self-reflection, a reassessment of one's meaning perspectives, having a dynamic analogous to the process of paradigm shift characterized by Kuhn (1970) with regard to scientific revolutions.

The Role of Dialogue

The second of the key processes of transformative learning pertains to the role of rational discourse, or, as Mezirow (2003) more recently refers to it, critical-dialectical discourse. Discourse refers to "the process in which we have an active dialogue with others to better understand the meaning of an experience" (Mezirow, 2000, p. 14). Mezirow (2003) contends that transformative learning involves critical reflection of assumptions performed independently or in interaction with others through communicative learning, where the validity of a transformed frame of reference requires participation in critical-dialectical discourse. Accordingly, in Mezirow's view, critical reflection on underlying assumptions is not a solitary activity, but is promoted, developed, and enacted through such dialogue devoted to assessing contested beliefs,

thereby leading to perspective transformation. Thus, it is in the realm of dialogue that personal experience and reflection start to intertwine and complement one another.

Developing the ability of adults to assess alternate beliefs and participate fully and freely in critical-dialectical discourse requires certain aptitudes. Skills relevant to facilitating productive engagement in this type of dialogue are considered by Mezirow as having an open mind, learning to listen empathetically, "bracketing" premature judgment, seeking common ground, and possessing qualities of emotional intelligence, such as self-motivation, persistence, impulse control and self-control (Mezirow, 2003). The ideal conditions for participants to engage in reflective dialogue include the importance of providing complete and accurate information, encouraging openness to alternative points of view, ensuring equal opportunities for the participation in various roles of the discourse, developing awareness of the context of ideas, and the ability to weigh arguments objectively, (Mezirow, 2000, p. 13-14). In addition to creating positive conditions for productive dialogue, the nature of dialogue – what participants are actually discussing – plays an important role. For instance, research showed that dialogue helped identify learners' "edge of meaning", defined as a space where "we can come to terms with the limitations of our knowing and thus begin to stretch those limits" (Berger, 2004, p. 338). This transitional zone of knowing and meaning making was revealed in a dialogue among students in a graduate program in education who had difficulties when discussing ontological issues about their personal lives (Berger, 2004).

Although research is limited concerning the role of dialogue in transformative learning, it is apparent that social interaction and dialogue lead to consensual validation among learners. Dialogue with self and the others becomes the medium for critical reflection on experience to be put into action, thereby promoting transformation (Baumgartner, 2002; Gordon and Brobeck, 2010; Jones, 2010; Sands and Tennant, 2010). Nonetheless, engaging in dialogue represents more than having a conversation, but it involves an awareness of learners' attitudes and ways of knowing, and the development of a sense of trust, thereby creating a comfort zone for learners while reaching their edge of knowing.

For instance, Cranton and King (2003) argued that "if we do not consciously think about and reflect on our practice, we become nothing more than automatons following a dubious set of rules" (p. 32). They maintained that effective professional development should bring academics' habits of mind about teaching into consciousness and allow them to examine critically, through reflection and dialogue, what they believe and value in their work as educators (Cranton and King, 2003). The reason for choosing transformative learning as the theoretical framework for the present study is that it places educators (science instructors) as adult learners with no formal teaching training who, while engaged in a professional development program, learn to teach through experience while reflecting on and discussing their practice.

The Scholarship of Teaching and Learning (SoTL) Movement

After a wave of production of PhDs in the 1960s, the number of doctorates awarded in science-related fields declined in the 1980s and 1990s, leading to a major change in the nature of academic employment. For example, the increase of part-time and short-time employment positions led to lower opportunities for academic promotion of non-tenured faculty that dealt mainly with teaching, and to longer waiting periods for promotion for tenured positions that dealt mainly with research (Youn and Price, 2009). Moreover, numerous studies have recognized research productivity, rather than successful teaching, as the dominant criterion for faculty reward among all types of higher education institutions nationwide (Boyer, 1990; Fairweather, 2005; Rhode, 2006; Winston, 1994).

Additionally, in the present university culture, graduate programs that prepare future academics give marginal attention to the advancement of pedagogical content knowledge, by placing emphasis on educating researchers through the advancement and dissemination of knowledge related to the discipline (Kreber, 2001). As a result, academics' proficiency lies in their subject area specialization and their knowledge about

teaching and learning is, in most cases, limited to the knowledge derived from practice. They may tend to teach as they were taught or to base themselves on a specific role model, a teacher who strongly influenced them as students. Very rarely, a new faculty member will develop a relationship with a teaching mentor. Nevertheless, most higher education institutions continue to adhere to the traditional notion that those who are experts in a content area are also well prepared to teach it. The only way to escape this dilemma is to consider teaching a scholarly activity.

As a result, a social movement called "the scholarship of teaching and learning" (SoTL) has gained momentum on campuses nationwide, with the purpose of improving teaching by making it a subject of academic inquiry (McKinney, 2007). In the sciences, this movement takes the name of scientific teaching (DeHaan, 2005; Handelsman et al., 2004). This movement started with Boyer's influential report (1990) sponsored by the Carnegie Foundation for the Advancement of Teaching, which intended to change the decisions on the retention, promotion, and tenure of academics. The report argued for four separate yet overlapping functions of the professoriate: scholarship of discovery, scholarship of integration, scholarship of application, and scholarship of teaching, as rankings of scholarship in the academe. While the *scholarship of discovery*, which referred to research productivity, remained one important criterion in defining scholarship, it remained inexorably linked to the *scholarship of integration* – connection among disciplines, the *scholarship of application* – application of knowledge in the society, and the *scholarship of teaching* – extension, transformation, and transmission of knowledge. These four forms of scholarship have started to form ever since into an interdependent whole.

A variety of models for the scholarship of teaching have been advocated since Boyer (1990) first proposed it as one of the four forms of scholarship in the academe. For instance, Martin, Benjamin, Prosser and Trigwell (1999) argue that SoTL comprises three activities: engagement with the existing knowledge on teaching and learning, self-reflection on teaching and learning in one's discipline, and public sharing of ideas about teaching and learning within the discipline. Also, Cambridge (2001, p. 4) defines SoTL as "problem posing about an issue of teaching or learning, study of the problem through

methods appropriate to the disciplinary epistemologies, applications of results to practice, communication of results, self-reflection, and peer review". More recently, Kreber (2002) describes four different conceptions of SoTL: the first considers it as the process by which academics conduct and publish research on teaching in their discipline (Healey, 2000; Richlin, 2001), the second views SoTL as teaching excellence (Morehead and Shedd, 1996), the third focuses on how academics make use of the research literature on teaching and learning to inform their practice (Menges and Weimer, 1996), and the fourth combines elements of the previous three and includes essential scholarly elements, such as reflection and dialogue (Kreber and Cranton, 2000). Also, Trigwell and Shale (2004) proposed a SoTL model which comprises three parts: 1) knowledge of the discipline, teaching and learning, context, and conceptions of teaching; 2) practice, which includes teaching, reflection, communication, and learning; and 3) outcome represented mainly by student and teacher learning. All these conceptions of the SoTL overlap considerably to include reflection on and communication about teaching, but the SoTL viewed through Kreber and Cranton's lens is based on Mezirow's (1978, 1981, 1990, 1991, 2000, 2003, 2009) transformative learning theory. Thus, this SoTL model serves as the larger context of the present study, in which academics are viewed as learners about teaching and learning who are engaged in the process of development as scholars of teaching.

More specifically, Kreber and Cranton (2000) developed their SoTL model by applying Mezirow's theory of transformative learning in the context of the development of teaching scholarship in higher education. Their model views college faculty as adult learners that engage in self-directed, collaborative, social, and institutional change. As outlined by other scholars (Andresen, 2000), this SoTL model places critical self-reflection at its core, considering that academics who engage in content, process, and premise reflection about teaching practice the scholarship of teaching (Kreber and Cranton, 2000). Also, this SoTL model maintains that knowledge of faculty about teaching comprises three qualitatively different knowledge domains: instructional, pedagogical, and curricular (Mezirow, 1991, 1990).

Critical self-reflection comprises content, process, and premise reflection (Mezirow, 1990, 1991). These facets of reflection can be explained in the context of this

SoTL model. Content reflection examines the content of a teaching problem ("What happened in my classroom?") and leads to the development of instructional knowledge (technical knowledge about course design). Process reflection involves examination of problem-solving strategies based on learning theories ("What have I done to cause the problem?") and is conducive to creating pedagogical knowledge. Pedagogical knowledge is in this case inclusive of Shulman's (1987) notions of discipline knowledge and pedagogical content knowledge, which include an understanding of learning styles, cognitive processes involved in learning, and group dynamics. Premise reflection is the questioning of the problem itself ("Does the problem really matter?") and leads to curricular knowledge (understanding of how courses fit together into a program). Subsequently, Kreber and Cranton (2000) propose these three interrelated domains of knowledge (instructional, pedagogical, curricular) as attributes of knowledge about teaching as scholarship in higher education (see Figure 1 below).

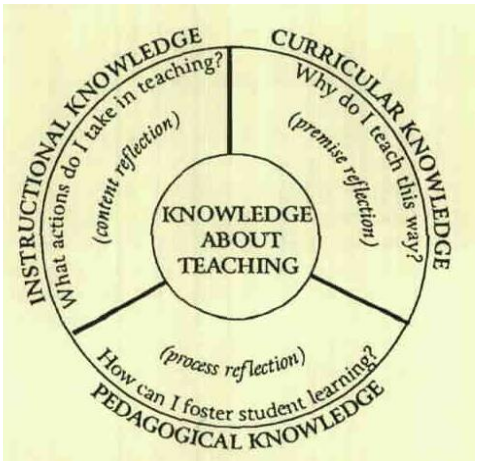

Figure 1 - Knowledge system of teaching

(Kreber and Cranton, 2000). Copyright 2000, Ohio State University. Reproduced with permission.

Additionally, by paralleling Mezirow's transformative learning theory, Cranton (1997) and Kreber and Cranton (2000) argue that there are three levels of learning that higher education faculty use to derive knowledge about teaching: instrumental,

communicative, and emancipatory. As mentioned previously, the instrumental learning relies on empirical evidence to prove the validity of an assertion, is manipulative of the learning environment, and is not applicative to moral or societal problems. Communicative learning refers to understanding learners, learning how to interact with them, and learning about teaching through communicating with others. The emancipatory learning is generated through critical self-reflection in order to overcome limitations of self-knowledge, leading to growth and development of self. It is through instrumental, communicative and emancipatory knowledge altogether that teaching scholarship is developed, when faculty critically question why they do what they do. Finally, when faculty engage in the three forms of reflection: content, process, and premise (Mezirow, 1991) on instrumental, communicative, and emancipatory knowledge within instructional, pedagogical, and curricular domains of knowledge about teaching, they develop scholarship in teaching. This yields a 3 x 3 matrix (see Figure 2) that represents the nine components of the SoTL model (Kreber and Cranton, 2000). Each of the nine components can be characterized by combinations of instrumental, communicative and emancipatory learning processes. As Figure 2 depicts, Kreber and Cranton's model argues that when faculty engage in content, process and premise reflection on instructional, pedagogical, and curricular knowledge, they develop SoTL.

Kreber and Cranton (2000) suggested that their model can be used to foster and assess the development of teaching scholarship. For instance, they proposed a list of indicators, or actions that demonstrated that faculty possessed or were in the process of developing SoTL. Their list, not considered comprehensive, contains three indicators for each kind of reflection in instructional, pedagogical and curricular knowledge. These indicators are based on criteria previously used to discriminate between scholarly work in general, and other types of academic work: the work requires high-level discipline-related expertise, is innovative, can be replicated, can be documented, can be peer-reviewed, and has a significant impact (Diamond, 1993). As such, when referring to the development of teaching scholarship, these indicators pertained to high-level expertise in teaching, application of innovative teaching methods and conducting action research, engagement in critical self-reflection and discourse, documentation through reflective essays and

teaching portfolios, publication of education papers, and evidence of impact of work through teaching evaluations.

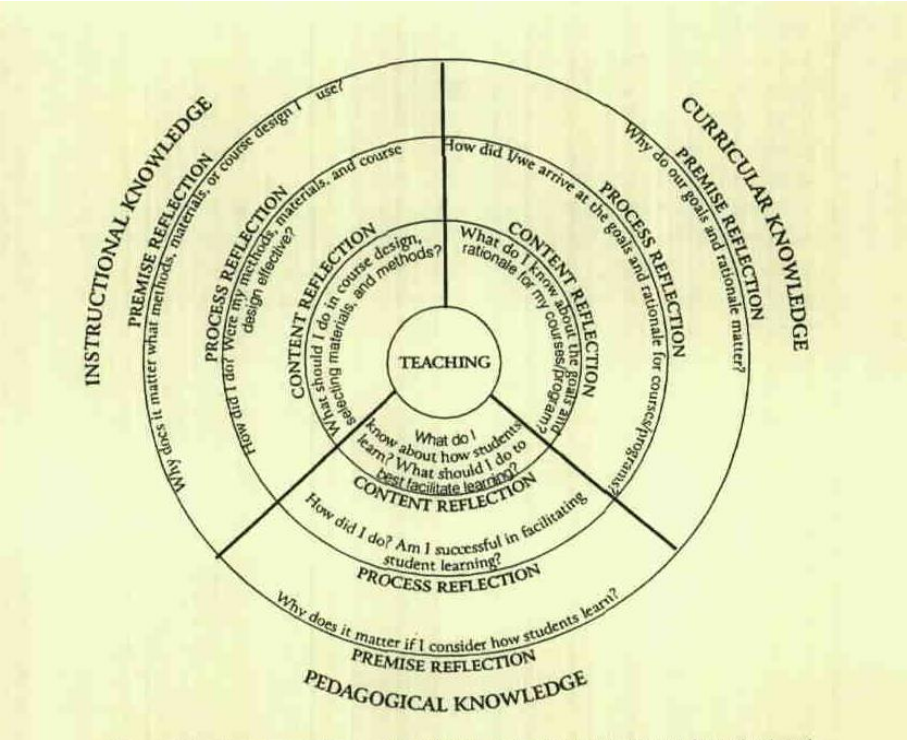

Figure 2 - Model of the scholarship of teaching

(Kreber and Cranton, 2000). Copyright 2000, Ohio State University. Reproduced with permission.

For example, teaching portfolios included various documents, such as a teaching philosophy statement, outlines of courses taught, unsolicited comments from students, examples of completed course work from students, and so forth. These portfolios are typically used to promote teacher growth and provide a basis for assessing teaching effectiveness (Baume and Yorke, 2002; Knapper, 1995; Smith, 1995), or to document development of teaching and of reflective practice (Klenowski, Askew and Carnell, 2006; Kreber, 2006b). Thus, acknowledging that there are two equally important sources of reflection on teaching, educational theory and teaching experience, Kreber (2006b)

analyzed teaching portfolios which included statements of teaching philosophy, course syllabi, and other teaching artifacts. Her analysis provided an empirically constructed list of concrete actions that can be used as indicators of engagement in reflection on teaching (see list below):

1. Describing the instructional strategies one uses (content reflection/instructional knowledge - experience-based);
2. Asking for peer review of course outline (process reflection/instructional knowledge - experience-based);
3. Collecting data on students' perceptions of methods and materials (process reflection/instructional knowledge - experience-based);
4. Experimenting with alternative teaching approaches and checking out results (premise reflection/instructional knowledge - experience-based);
5. Comparing different instructional strategies for their suitability in a given context (premise reflection/instructional knowledge - experience-based);
6. Paying attention to end of term teaching evaluations (process reflection/instructional knowledge - experience-based);
7. Writing critiques on “how-to teaching books” (premise reflection/instructional knowledge - research-based);
8. Administering learning styles or other inventories to students (process reflection/pedagogical knowledge - research-based/experience-based);
9. Writing an article on how to facilitate learning in the discipline and submit it to a scholarly journal (content/process reflection/pedagogical knowledge – research-based);
10. Gathering feedback from students on their learning of discipline-specific concepts (process reflection/pedagogical knowledge - experience-based);
11. Comparing research-based insights gained from courses on teaching and learning to one’s knowledge of how students learn (process reflection/pedagogical knowledge - research-based);
12. Listening to others, observing how others learn, and discussing or writing about it (process reflection/pedagogical knowledge - experience/research-based);

13. Reading articles or books on learning and developmental theory (content reflection/pedagogical knowledge - research-based);
14. Observing others teach and observing the reactions of their learners (process reflection/pedagogical knowledge - experience-based);
15. Conducting an action research project on student learning (process reflection/pedagogical knowledge - research-based);
16. Presenting findings from classroom teaching experiments at teaching-related sessions at conferences (process reflection/instructional knowledge – research-based);
17. Showing how goals of one's teaching relate to what students need to live successful lives (process reflection/curricular knowledge - experience-based);
18. Consulting with an educational development specialist (process reflection/pedagogical knowledge - research-based);
19. Comparing classroom experience to formal research results on student learning (process reflection/pedagogical knowledge - research-based);
20. Explaining how and why goals have changed over time (premise reflection/curricular knowledge - experience-based);
21. Consulting with employers to see what goals they have in mind (premise reflection/curricular knowledge - experience-based);
22. Participating in a curriculum review committee (premise reflection/curricular knowledge - experience-based);
23. Participating in philosophical discussions on student learning, for example through a listserv or with colleagues (premise reflection/pedagogical knowledge - experience-based);
24. Reading books on the goals of higher education and comparing goals to those underlying the programs offered in the department (process reflection/curricular knowledge - research-based);
25. Writing articles that compare the usefulness of textbooks in one's field and compare outcomes of analysis to own text and course content (process reflection/curricular knowledge - research-based).

In this large context of the scholarship of teaching and learning (SoTL) movement in higher education, efforts to enrich college science teaching and learning have been growing. These efforts are collectively grouped under professional development initiatives sponsored by higher education institutions. Their final goal is to induce major changes in teaching practices that have the potential to positively impact student learning and engagement. For instance, meaningful professional development is viewed through Kreber and Cranton's model (2000) as an opportunity to interrogate values, beliefs, and assumptions about teaching, and to cultivate transformative learning. This questioning, or critical self-reflection on teaching, leads in turn to changing habits of mind, acquiring alternative ways of understanding teaching, and finally changing the practices of teaching (Cranton and King, 2003; Kreber, 2006b; Kreber and Cranton, 2000).

Professional Development in Higher Education

A recent interdisciplinary literature review that included 130 research studies focused on approaches to improve undergraduate science education, identified four different change strategies: 1) disseminating curriculum and pedagogy, 2) developing reflective teachers, 3) developing policy, and 4) developing shared vision (Henderson, Finkelstein and Beach, 2010). Very importantly, Desimone (2009) suggested that studies of effectiveness of professional development should focus on the core features that are known to be related to teacher learning and changing practice, rather than on the structure of these activities (e.g., workshop, study group). For example, previous research studies that involved science teachers, showed that the core features of effective professional development included engagement in active learning, coherence, duration, and collective participation (Garet et al., 2001; Heck, Banilower, Weiss and Rosenberg, 2008; Jeanpierre, Oberhauser and Freeman, 2005; Penuel, Fishman, Yamaguchi and Gallagher, 2007).

There is a great deal of controversy in the literature regarding the training of postsecondary teachers and its impact on teaching and student learning. For instance, regarding the transition from teacher-centered to student-centered teaching, Gibbs and Coffey (2004) found that students took a surface approach to learning to a lesser extent after their instructors had been trained. Hence, they argued that instructor training in higher education should be oriented towards changing teaching approaches to student-centered, which has an impact on students' approaches to learning. Yet, their study does not describe in detail what teaching training means other than mentioning the amount of time their study participants spent in formal training programs focused on teaching and learning. Moreover, additional research studies (Postareff, Lindblom-Ylanne and Nevgi, 2007, 2008) showed that teaching training programs that span over a long time have a positive impact on the transition from teacher-centered to student-centered teaching approaches, as self-reported through the Approaches to Teaching Inventory (ATI; Prosser and Trigwell, 1999; Trigwell and Prosser, 2004). On the other hand, several studies found little evidence to conclude that teaching training has an effect on teaching conceptions and behaviors, or on student learning (Gilbert and Gibbs, 1999; Henderson, Finkelstein and Beach, 2010; Norton et al., 2005; Weimer and Lenze, 1997).

The National Research Council (1996) recommends that science teachers be continuously involved in thoughtful reflection, interaction with peers, and trial and error teaching situations in order to develop an integrated understanding that characterizes expert teachers of science. As such, after reviewing the research literature on approaches to improve science teaching in higher education, Henderson and colleagues (2010) concluded that an important change strategy that emerged from the literature was to develop reflective instructors. They argued that developing reflective instructors can be done in various ways, such as through individual consultations with an experienced faculty developer (Piccinin, Cristi and McCoy, 1999), by providing faculty with information about and tools for innovative instructional approaches (Henderson, 2008), encouraging faculty to engage in inquiries within their own classrooms through action research and the development of the scholarship of teaching and learning (Connolly, Bouwma-Gearhart and Clifford, 2007; Kember and McKay, 1996), and fostering faculty

collaboration on instructional development (Krockover et al., 2002; Stevenson, Duran, Barrett and Colarulli, 2005).

On the whole, encouraging faculty to reflect on their teaching is recognized to lead to improved instruction and is considered a core feature of professional development (Brookfield, 1995). The research literature on the development of reflective instructors demonstrates that through this approach to improving undergraduate science teaching, faculty bring their knowledge and experience into the change process and hence, have ownership of the emergent instructional changes, which are customized to the instructor and the teaching environment (Henderson, Finkelstein and Beach, 2010). Nonetheless, it is important to acknowledge the disadvantages of this approach, such as a substantial time commitment from faculty without reduction in other responsibilities, in the context of the traditional higher education environment that continues not to reward a focus on teaching.

Transformative Professional Development

Findings extracted from research studies informed by transformative learning theory, mostly those that focus on critical self-reflection and engagement in dialogue as ways of facilitating learning how to teach in higher education, are especially relevant to the present study. Results from such studies are discussed henceforth for the purpose of placing the current work in the large context of research on learning to teach in higher education.

Similar to what was found previously (Taylor, 2000), a recent review of research on transformative learning involving 40 studies published in peer-reviewed journals between 1999 and 2005 (Taylor, 2007), identifies that their focus continues to gravitate around critical reflection, relationships, and context, as catalysts of transformative learning. Also, while qualitative designs continue to predominate, they have become more sophisticated to include longitudinal and mixed-method approaches (Taylor, 2007). Even though Taylor (2007) contends that research employing transformative learning as theoretical framework continues to be situated in higher education settings, more

recently, a growing number of research studies have shifted their focus on workplace and community (Fenwick, 2008; Meyer, 2009; Tyler, 2009).

An early qualitative study (McAlpine and Weston, 2000) employed six academics recognized for their teaching excellence and explored the role of reflection in the process of constructing knowledge about teaching, to elaborate a model of metacognitive processes of reflection. Excluding analysis of teaching actions and building only on interview data, researchers found that reflection is anchored in experience, which leads to monitoring teaching to track achievement of goals, directing in turn to decision-making processes that guide modification of teaching actions. The ongoing processes of monitoring, reflecting and decision-making are essential to building teaching knowledge, which may originate from self-evaluations of teaching, trial and error in one's own teaching, and student feedback (Hativa, 1997). In other words, linking knowledge and experience to future action through reflection has the likelihood of improving thinking about teaching and carries a great potential to improve enactment of teaching.

A qualitative study performed by Gravett (2004) analyzed the teaching conceptions of sixty academics from three institutions, who were involved in a series of four workshops designed to teach them how to employ student-centered teaching in parallel with stimulating scrutiny of their teaching through reflection and dialogue. Gravett argues that transformations towards student-centered teaching perspectives can be induced through a professional development strategy informed by the transformative learning theory. Moreover, she maintains that implementation of student-centered teaching practices involves additional support from professional developers and peers, therefore providing important information for the organization of future professional development initiatives. This study strengthens the argument widely recognized in the literature, namely that workshops or short courses do not represent effective professional development strategies, and that continued support, and engagement in reflection and dialogue, may increase the likelihood for the implementation of learned instructional approaches.

One landmark study conducted by Kreber (2005) looked at the applicability of the SoTL model of reflection, empirically identified similar indicators of reflection on

knowledge about teaching as initially proposed (Kreber and Cranton, 2000), and established a correlation between instructors' beliefs and conceptions about teaching and their engagement in reflection. This research employed a mixed-method approach in which thirty six college science instructors were engaged in semi-structured interviews based on the SoTL model, and completed the Approaches of Teaching Inventory (Prosser and Trigwell, 1999). As a result of this study, Kreber concluded that, while there were more declarations of reflection than concrete indicators of reflection, premise reflection, the questioning of presuppositions or "critical reflection" (Mezirow, 1991), was the least observed form of reflection across all three knowledge domains. Reflections occurred mostly within the domain of instructional knowledge, immediately followed by pedagogical knowledge, and only sporadically within curricular knowledge. Moreover, the study identified that academics who espouse teacher-centered conceptions about teaching engage in content reflection on instructional knowledge, whereas faculty who espouse student-centered conceptions about teaching are more likely to engage in all three types of reflection across all three domains of knowledge. These findings come in accord with previous research (Valli, 1992), which showed that teachers' own conceptions about teaching may serve as obstacles to the implementation of a reflective teacher education program. While Kreber's study (2005) concluded that conceptions about teaching may influence academics' motivation to engage in reflection, it did not look at how professors teach, to link their actual teaching approaches to their conceptions and engagement in reflection.

Recent research combined Mezirow's transformative learning with Vygotsky's sociocultural theory (1978) and, based on the action research theoretical framework (Carr and Kemmis, 1986), proposed an Expanded Reflection Cycle for Transformative Professional Learning (Lebak and Tinsley, 2010; Tinsley and Lebak, 2009). These studies found that teachers engaged with peers in collaborative reflection on teaching after watching teaching videotapes of group members, changed their pedagogical approaches from teacher-centered to student-centered orientations, and their level of perspective transformation rose in proportion to their teaching experience. Moreover, by extending Vygotsky's concept of the zone of proximal development (1978), Tinsley and

Lebak (2009) suggested that the professional growth of teachers occurred in a zone of reflective capacity that shares the attributes of the zone of proximal development (Vygotsky, 1978). They argued that the reflective capacity is constructed and expanded through positive interactions among participants engaged in collaborative reflection triggered by watching videos of teaching. Even though actual analyses of teaching videos are not taken into consideration, it is important to note that both studies report watching videos of teaching as trigger of a new reflection cycle finally leading to a transition to student-centered teaching.

Action research is seen as having a unique compatibility with transformative learning, as it provides a pedagogical framework for promoting change and enrichment of teaching beliefs and practices (Lange, 2004; Percy, 2005; Taylor, 2007). In recognition of the National Board for Professional Teaching Standards, it has been long recommended that action research incorporating reflective teaching, inquiry into one's practice, and peer collaboration be adopted as foundation for teacher education programs (Diez and Blackwell, 1999; Richert, 1990; Zeichner, 1983), in order to provide opportunities for teachers to enact theory into practice, deal with teaching complexity and analyze teaching and learning. Moreover, Zeichner (2007) suggests that self-study research in teacher education should contribute to the improvement of teacher education practice and to the broader knowledge about the significance of particular issues for teacher educators and policy makers. For instance, Darling-Hammond and Baratz-Snowden (2005) assert that graduate programs need to provide opportunities for teachers to enact theory into practice and deal with teaching complexities by learning to analyze teaching and learning. Even though received with reticence by pre-service teachers (Zambo and Zambo, 2007), recent research studies showed that incorporating action research in teacher education has a positive impact on the development of critical thinking skills and allows for strong connections between practice and education theories (Ostorga and Estrada, 2009; Ward and McCotter, 2004). Particularly in the field of science education, for example, participation in action research during teacher training increases the likelihood of engagement in reflective practice and inquiry into classroom actions after graduation (Hohloch, Grove and Bretz, 2007).

In the current climate in higher education, reflective practice is inextricably related to continuing professional development, putting academics at the center of their own learning and self-development (Norton, 2009). "Systematic reflection in the form of action research can provide the stimulus for changing and improving practice" (Mertler, 2006, p. 14) and can have a valuable role in promoting a conceptual change approach to science teaching (Tabachnick and Zeichner, 1999). For instance, Hubball, Collins and Pratt (2005) used the Teaching Perspective Inventory (Pratt and Collins, 2001) to quantitatively measure the change of academics' philosophical orientation and teaching conceptions after involving them in a long-term faculty development program that facilitated in various ways critical self-reflection on teaching. They found that such a faculty enrichment program which provides structure and guidance for engaging in critical reflection on teaching leads to positive changes in academics' perspective on teaching. Additionally, Gravett and Petersen (2009) report that reflection embedded into a large-enrollment teaching methodology course for adult educators proved to be crucial for helping learners move from espousing a new teaching methodology toward implementing it in a reflective manner.

This reflective process encourages academics to take control of their own professional development by being active learners. Moreover, as opposed to traditional teaching workshops for newly appointed faculty, participation in collaborative action research provides a more supportive atmosphere conducive to generating opportunities to validate and contest tacit knowledge about teaching, challenge ideas and values, and gain support for immediate needs (Staniforth and Harland, 2003). On the other hand, few studies (Gravett, 2004; Raubenheimer and Myka, 2005) have shown that engagement in action research as inquiry into one's own teaching leads to transformation of teaching towards student-centered approaches that is known to positively impact college students' learning approaches.

Teaching and Learning Approaches

The world, as we experience it day by day, is non-dualistic. In other words, teachers' and students' experiences are not isolated one from the other, but they are constituted in relation to each other in the realm of teaching and learning in which they both are engaged (Prosser and Trigwell, 1999).

Teachers' conceptions, or beliefs, lie "at the very heart of teaching" (Kagan, 1992, p. 85). Hence, teachers' approaches to teaching are commensurate with their conceptions of teaching. Many previous research studies showed that academics' conceptions of teaching range from teaching as transmitting knowledge, to teaching as facilitating understanding and conceptual change (e.g., Kember and Kwan, 2000; Samuelowicz and Bain, 1992, 2001). For instance, teachers who conceive teaching as imparting knowledge are more likely to adopt a teacher-centered, transmission approach to teaching, through which students are seen as passive recipients and learning outcomes are expressed in quantitative terms, without concern for students' understanding of knowledge. Conversely, teachers who view teaching as facilitative and interactive, are more likely to adopt a student-centered approach to teaching, through which students are actively learning and engaging in a conceptual change process.

Very importantly, while transitions from teacher-centered to student-centered conceptions of teaching have been documented in the literature (Samuelowicz and Bain, 2001; Trigwell and Prosser, 1996a), research shows that enormous efforts are needed to accomplish change of underlying conceptions of teaching (Kember, 1997). In contrast, Gibbs and Coffey (2004) argue that the purpose of instructors' training in higher education should be more towards changing their approaches to teaching to student-centered approaches, change which leads to consistent effects on learning processes and outcomes.

Despite findings reported by Trigwell and Prosser (1996b), who found a congruence between instructors' conceptions and approaches to teaching, a review of approximately 50 research studies on academics' conceptions about teaching concluded that there is insufficient support for a relationship between espoused conceptions and

actual teaching practices (Kane, Sandretto and Heath, 2002). More recently, Olafson and Schraw (2006) confirmed that there are inconsistencies between teaching conceptions and approaches espoused by teachers and their actual teaching practices. To this end, when evaluating academics' changes in teaching approaches after their engagement in professional development programs, teaching approaches should be corroborated with observation of teaching practices. For instance, the Reformed Teaching Observation Protocol (RTOP) was created as an observational instrument designed to evaluate instruction in terms of the extent to which it incorporates student-centered, active learning practices (Sawada et al., 2000). The RTOP has been previously used by others (Lawson et al., 2002) to evaluate instruction in college science classrooms and strong correlations were found between RTOP scores and student learning, as measured by students' test scores. RTOP consists of 25 observations about the extent to which student-centered teaching methods (e.g., teaching through active learning), are incorporated in instructional practice.

Nonetheless, teaching approaches have been shown to be influenced by several other factors, aside from discipline and conceptions about teaching, such as teachers' perceptions of the teaching environment (Lindblom-Ylanne, Trigwell, Nevgi and Ashwin, 2006; Samuelowicz and Bain, 1992), personality characteristics (McKeachie, 1997), styles of thinking (Zhang and Sternberg, 2002), or level of teaching experience (Prosser, Ramsden, Trigwell and Martin, 2003).

Based on students' perceptions about their learning environments, students' approaches to learning have been divided into two qualitatively different categories: deep and surface (Biggs, 1979, 1987; Entwistle and Ramsden, 1983; Marton and Saljo, 1976, 1997). Students that use deep approaches to learning aim to seek meanings and understand concepts, have an intrinsic interest, and an expectation of enjoyment when satisfying their curiosity. Students that use a surface approach see learning as an external imposition and are pragmatically motivated to meet learning requirements with minimum effort, they memorize facts for assessment purposes rather than for understanding, and are involved with studying without reflecting on its purpose and application. More recently, a strategic approach to learning has been identified, which pertains more to

students' self-regulatory skills, such as organization, time management skills, effort and concentration (Entwistle and McCune, 2004; Entwistle, McCune and Walker, 2001; Entwistle and Peterson, 2004).

Approaches to learning are related to students' perceptions of their learning environments. For instance, there is strong evidence that deep approaches to learning are positively correlated to learning environments that encourage understanding and promote active student engagement (Entwistle and Peterson, 2004; Entwistle, Tait and McCune, 2000; Handelsman et al., 2004; Prosser and Trigwell, 1999; Richardson, 2005; Sadlo and Richardson, 2003; Trigwell and Prosser, 1991). In these environments, students are more likely to perceive a high quality of teaching and feel that while there is a choice of what is to be learned, clear goals and standards of learning are also present. Thus, deep learning is stimulated by student-centered teaching approaches that promote active learning, and leads to increased student engagement with ideas and concepts, and enjoyment of intellectual challenge.

For instance, despite an absence of data from actual observations of teaching, previous quantitative studies that looked at science teaching and learning in higher education have established strong correlations between conceptual change-based, student-centered science teaching approaches and students' deep approaches to learning of science (Kember, Leung and McNaught, 2008; Kreber, 2003a; Prosser, Hazel, Trigwell and Lyons, 1996; Trigwell and Prosser, 1996b; Trigwell, Prosser and Waterhouse, 1999). These quantitative studies explored the correlation between instructors' approaches to teaching and students' approaches to learning by using the Approaches to Teaching Inventory (ATI). The ATI was developed by Prosser and Trigwell from the identification of qualitatively different conceptions and approaches to teaching (Prosser and Trigwell, 1999; Trigwell and Prosser, 2004). This instrument combines questions in the conceptual change/student-focused approach scale with items in the information transmission/teacher-focused approach to teaching scale. Moreover, the same instrument has been used by previous researchers, either to measure changes in teaching approaches of academics involved in various professional development programs (Gibbs and Coffey, 2004; Postareff, Lindblom-Ylanne and Nevgi, 2007, 2008),

or to corroborate conceptions of and approaches to teaching with a model of reflection about science teaching (Kreber, 2005), or with academics' decisions in planning to teach (Eley, 2006).

Nevertheless, while it is known that various disciplines have their shared concepts, theories, methods, and techniques, this disciplinary variation leads to variations in approaches to learning, as well as approaches to teaching and engagement with scholarship of teaching (Neumann, Parry and Becher, 2002; Smith and Miller, 2005). As such, previous quantitative studies showed that instructors who teach in the 'hard sciences', such as physical sciences, medicine or engineering, were more likely to apply an information transmission/teacher-focused approach to teaching, whereas instructors from 'soft' disciplines, such as humanities and social sciences, tended to adopt a conceptual change/student-focused teaching approach (Kember, Leung and McNaught, 2008; Lindblom-Ylanne, Trigwell, Nevgi and Ashwin, 2006; Lueddeke, 2003). Moreover, within the larger community of science educators, Tsai (2007) showed that teachers who embrace constructivist epistemologies tended to foster the creation of a student-centered environment by focusing on student understanding and application of concepts and promoting active learning, whereas positivist-oriented educators tended to allocate more time on teacher-centered lectures. In accord with the abovementioned studies, corroborating research shows that students who study in the 'hard' sciences score higher for a surface approach to learning than students who study in the 'soft' disciplines, thereby emphasizing teachers' role in facilitating learning (Parpala et al., 2010; Virtanen and Lindblom-Ylanne, 2010). These research-based considerations may be regarded as intrinsic barriers to the implementation of student-centered teaching and deep learning in the sciences.

Student Engagement as Active Learning

As Angelo and Cross (1993, p. 3) point out, learning can take place without teaching, but teaching cannot happen without learning; "teaching without learning is just talking". Hence, the unifying thread between teaching and learning is student engagement (Barkley, 2010). Pascarella and Terenzini (1991) were the first to pair learning with

student engagement, arguing that the greater the students' engagement with academic work, the greater their levels of knowledge acquisition and general cognitive development. Consecutively, Edgerton (1997) coined the idiom *pedagogy of engagement*, which connected students' conceptual understanding with teaching approaches that stimulate active learning.

Meanwhile, the National Survey of Student Engagement (NSSE) became involved with measurements of student engagement in post-secondary education, by approaching it dichotomously: On one hand, it looks at the frequency with which students participate in activities and interactions in and out of the classroom, as part of effective educational practices. On the other hand, it explores the ways institutions deploy their resources and organize the curriculum to get students to actively participate in activities scientifically linked to student learning (NSSE, 2010). Recognizing how institutional and classroom influences intertwine, NSSE (2010) established five clusters of effective educational practices which link classroom and institutional experiences, and that are considered benchmarks for measuring student engagement. These are represented by 1) level of academic challenge, 2) active and collaborative learning, 3) student interactions with faculty members, 4) enriching educational experiences, and 5) supportive campus environment (Kuh, Kinzie, Schuh and Witt, 2005).

Barkley (2010, p. 6) maintains that student engagement is the product, rather than the sum, of student motivation and active learning. She goes on to say that "engagement may be […] described as a double helix in which active learning and motivation are spirals working together synergistically, building in intensity, and creating a fluid and dynamic phenomenon that is greater than the sum of their individual effects" (Barkley, 2010, p. 7). Thus, engaged learning is an active process leading to change and, from this perspective, can be equated with transformative learning, "a process by which previously uncritically assimilated assumptions, beliefs, values, and perspectives are questioned and thereby become more open, permeable, and better justified" (Cranton, 2006b, p. vi).

"Active learning means that the mind is actively engaged" (Barkley, 2010, p. 17). Active learning is characterized by a dynamic participation in the learning process, while students continuously reflect on and monitor both the processes and the results of their

learning. This definition of active learning that involves the students making connections between newly learned concepts and their existing knowledge and experiences, is critical to student engagement. Bonwell and Eison (1991, p. 2) were the first to provide a working definition of active learning as "anything that involves students in doing things and thinking about the things they are doing". Compared to lecture-based courses, where students only listen and take notes, students play many roles in active learning: students are engaged in activities and involved in higher order thinking processes (analysis, synthesis, evaluation), while developing skills and exploring their own attitudes and values (Bonwell and Eison, 1991). Dee Fink (2003) expands on this previous description of active learning by recognizing that active learning can be divided into two components: experiences and reflection, where the experiences, or "doing things", can also be separated into doing and observing (see Figure 3 for a comparison between passive and active learning).

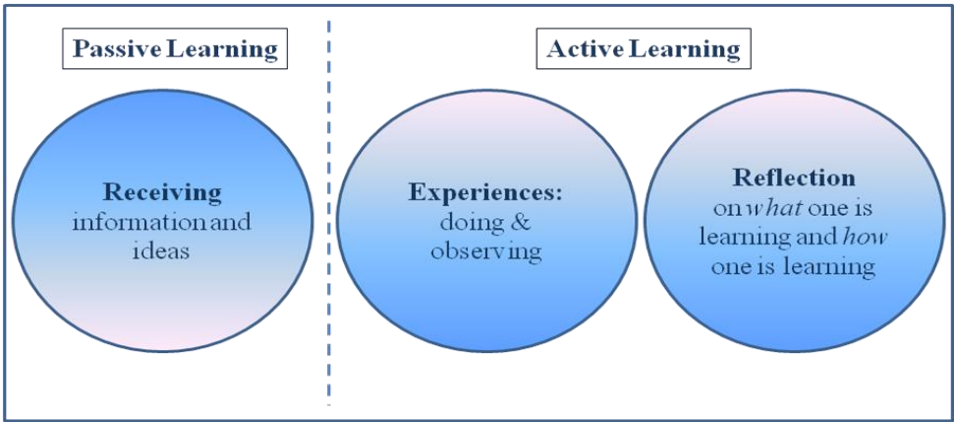

Figure 3 - Passive and active learning (adapted from Dee Fink, 2003).

Active learning generally refers to teaching approaches that involve students working individually or in groups on tasks related to the course objectives. It includes learning activities that engage students in interacting with one another and the instructor while learning and applying the course material: answering questions, solving problems,

troubleshooting, brainstorming, and in general, doing anything but watching a lecture. According to Johnson, Johnson, and Smith (1998), teaching for active learning is constructed on the following principles: 1) students actively construct their knowledge, 2) knowledge is discovered, transformed, and extended by students, 3) learning is a social enterprise in which students interact with the instructor and peers, 4) faculty effort is aimed at developing students' skills and competencies.

Active learning requires that instructors shift their pedagogical framework from a deductive to an inductive mode of teaching (Prince and Felder, 2007), when students are presented with problems or case studies to solve, leading to learning of the relevant principles or theories. Moreover, interactive learning strategies, which involve extensive active collaboration among students and between students and the instructors, are equated with student-centered teaching, as opposed to teacher-centered teaching, in which students are passive listeners facing a passive approach to teaching, such as traditional lecture (Prince, 2004). Furthermore, student-centered college faculty tend to use a more diverse repertoire of teaching methods than faculty who adopt teacher-centered approaches (Coffey and Gibbs, 2002). Handelsman and collaborators (2004) maintain that scholarly teaching in the sciences (scientific teaching) also involves active learning strategies, which have been systematically tested in science education research, and demonstrated their effectiveness in promoting engagement of diverse students (Handelsman, Miller and Pfund, 2007).

Summary

While under a continuous increase in college enrollment, the present economic pressures on colleges and universities have led to large class sizes, especially for introductory courses. After reviewing research on large classes, Chism (1989) affirmed that a large class frequently consists of one hundred or more students, and this has become the operational definition of a large class in the literature, which will also be

maintained throughout this study. Many introductory science courses cover vast quantities of information and have a competitive atmosphere (Bok, 2006). Consequently, on average, more than 25 percent of students are lost or choose to transfer into other academic fields by the start of the second year and thus, these courses are viewed as gatekeepers (Baldwin, 2009; Eagan and Jaeger, 2008; Seymour and Hewitt, 1997; Tobias, 1990). Most importantly, this is due to the fact that passive student roles in the lecture format continue to be embedded across disciplines at university level and are especially prevalent as tools of choice for large classes (Lammers and Murphy, 2002).

After looking into the literature on large classes, Litke (1995) summarized the beliefs and challenges that faculty commonly hold about teaching large classes: The five specific areas of concern for faculty are impersonality, deterrence of active learning and class participation, limitations of student evaluation, and reliance on the lecture format. More specifically, a recent study (Michael, 2007) that looked at teachers' perceptions concerning the implementation of active learning, reported three categories of challenges that pertain to student characteristics (e.g., students are unwilling, immature and not prepared to do active learning, etc.), teacher characteristics (e.g., extended time for course preparation, risk of poor student evaluations, less control from the part of the teacher, etc.), and pedagogical issues (e.g., class size and classroom setting not amenable to active learning, extended time required at the expense of content coverage, etc.). Despite perceived challenges, a plethora of research on the implementation of active learning in large classes demonstrates that they can be implemented efficiently in this setting and in teaching of various disciplines (e.g., Allen and Tanner, 2005; Allen, 1996; Carmichael, 2009; Crull and Collins, 2004; Ebert-May, Brewer and Allred, 1997). Nevertheless, large introductory science courses combine a diverse student population and thus, are perceived difficult to teach, which in consequence leads to academics' reliance on passive, teacher-centered, approaches to teaching. This suggests the need for the organization of professional development programs aimed at facilitating the implementation of student-centered teaching strategies by college science faculty.

Grounding their considerations in transformative learning theory, many leading scholars in the field (Cranton, 1994; Kreber, 2001, 2006a, 2006b) have long argued for a

professional development model that fosters transformative learning about teaching through recognition and revision of assumptions about teaching practice in the course of critical reflection and dialogue. This model by which faculty become self-directed adult learners learning how to learn about their teaching, they argue, involves long-term work with faculty developers who function as "challengers, supporters, models, resource people, and co-learners in the process" (Cranton, 1994).

Many research studies recognize critical reflection as an important practical component of the scholarship of teaching (Andresen, 2000; C. Kreber, 2002, 2003b; K. Trigwell, Martin, E., Benjamin, J., Prosser, M., 2000), where reflection functions as means of validating theory through practice (Jarvis, 1999). Hence, facilitating and then demonstrating faculty engagement in critical reflection on teaching would imply, through following Mezirow's theoretical framework, that they develop scholarship of teaching through transformative learning. While Kreber and colleagues (C. Kreber, 2005; C. Kreber, and Cranton, P., 2000) conceptualized and empirically identified indicators of reflection, more recently it has been proposed that transformative learning through reflection on teaching can be convincingly documented through the analysis of teaching philosophy statements, outlines of courses taught and other teaching artifacts, which can provide an objective interpretation of the enactment of student-centered conceptions about teaching as exponent of scholarship of teaching (Kreber, 2006b). As proposed in the transformative learning literature, the presence of indicators that suggest faculty engagement in process and premise reflection in the domains of curricular, pedagogical and instructional knowledge would imply faculty engagement in testing the validity of their assumptions. It follows that transformative learning takes place only if assumptions about teaching and learning are not validated through reflection. Kreber (2006b) goes on to argue that a change in teaching practice takes place as a result of engagement in transformative learning, but it also depends on a combination of other factors, including personal, social, and contextual.

In previous studies that focused on the role of engagement in critical reflection and dialogue in facilitating implementation of change in teaching (Gravett, 2004; Gravett and Petersen, 2009; Pohland and Bova, 2000), academics reported that being involved in

these practices was not sufficient, and that they needed additional explicit guidance and ongoing institutional support to successfully enact changes in teaching strategies. More specifically, Kreber (2001) suggests that faculty development aimed at promoting the scholarship of teaching, among other recommendations, should use workshops based on educational theory and research, and allow for sustained post-workshop collaboration and dialogue between faculty and developers.

The purpose of this study was to investigate science instructors' teaching conceptions, approaches and practices throughout their participation in a professional development program whose purpose was to support them in implementing active learning techniques in their large-enrollment courses. Essentially, the final goal of the program was to assist instructors of large science courses in learning ways to promote better student engagement, deepen students' learning of science, and to lower attrition rates in their classes. More specifically, the program was grounded in research informed by transformative learning theory, and was designed to create opportunities for participants' engagement in reflection and dialogue about teaching. The research questions that guided this study are:

1) What are participants' conceptions about teaching large science courses?
2) How do participants' teaching approaches transform after engaging in reflection and dialogue on their teaching?
3) To what extent are these transformations reflected in their teaching practices?

CHAPTER III
METHOD

Using Mezirow's transformative learning as a theoretical framework, this study explored science instructors' conceptions about and approaches to teaching large science courses combined with their teaching practices, throughout their participation in a professional development program. The critical features of this professional development program, namely participants' engagement in critical self-reflection and dialogue about their enactment of teaching strategies that promoted active learning, were seen as catalysts for the development of the SoTL. Thus, this study described how science instructors modified their teaching conceptions, approaches, and behaviors while engaged in transformative learning about how to endorse student active learning in large science courses.

This chapter is organized as follows: First, the connection among the theoretical framework and the methodological approach used is described, followed by more profound procedural aspects of the study. This includes a detailed explanation of the professional development program in its bounded system, namely the context, the study participants, and the role of the researcher. Second, data sources and data collection procedures are described. Finally, a depiction of the data analysis procedure that revealed the connections among the theoretical framework, research questions of the study, and data analysis.

Study Design

As proposed by Mezirow, "to understand communicative learning, qualitative research methods are often more appropriate" (Mezirow, 2003, p. 59). In consequence, the investigative approach employed by this research was multiple case study methodology. In general, case study methodology provides a systematic way of looking

at a phenomenon, in this case the professional development program, collecting data from multiple sources, analyzing and reporting the results with the goal of gaining a greater understanding of the phenomenon, and identifying important features to be investigated in future research (Gerring, 2005). As suggested by case study researchers (Gerring, 2005; Stake, 2006; Yin, 2009), case study methodology was selected because it recognizes the importance of context, focuses on the elucidation of conceptions, and enables in-depth examination of a contemporary phenomenon within its real-life context (participation in the professional development program). Overall, the researcher's purpose was to use the lens of transformative learning theory in order to follow Desimone's (2009) proposition and to study teachers' transformations in order to increase our understanding about how to best design professional development that will improve practice.

Regarding multiple case study methodology in particular, Stake (2006) states that multicase research starts with the *quintain*. He defines the *quintain* as the phenomenon to be studied by analyzing individual cases for what they inform the researcher about the *quintain*. Because the multicase study focuses on the *quintain* by going beyond individual cases, it is considered instrumental, as opposed to the intrinsic case study, where the enduring interest is in the case itself (Ary, Cheser Jacobs and Sorensen, 2010; Stake, 2006). Based on these considerations, this study employed the multiple case study methodology mainly because, as stated by respected scholars in the field (Ary, Cheser Jacobs and Sorensen, 2010; Creswell, 2009; Gerring, 2005; Stake, 1995, 2006; Yin, 2009), it is regarded as a powerful tool for the exploration of the relationships among two or more cases believed to be literal replications. Consequently, the focus of this study was to understand why and how science instructors modified their teaching approaches and behaviors while engaged in the professional development program. Individual cases are represented by science instructors involved in the program, who therefore were participants in a workshop and subsequently engaged in reflection and dialogue about learning how to use student-centered teaching throughout the post-workshop part of the program. As with the majority of multiple case studies, individual cases were considered

based on the assumption that they are literal replications, thus predicting to provide similar results, and hence, informing about various aspects of the program (Yin, 2009).

As mentioned previously, research studies that use the lens of transformative learning theory are predominantly performed through qualitative (e.g., Liimatainen, Poskiparta, Karhila and Sjogren, 2001; Yoon and Kim, 2010) or mixed-method approaches (Kreber, 2005). Only very recently, a quantitative study reported the incidence of precursor steps of transformative learning for students in post-secondary education (Brock, 2010). Relevant to the design of this study are research studies that employ the same theoretical framework and are conducted through a case study methodology. For example, an action research project informed by transformative learning theory used case study methodology to describe the change of perspectives and practices of instructors from teacher-centered to student-centered (Gravett, 2004). Recently, Lebak and Tinsley (2010) performed a multiple case study that explored the transformations of pedagogical approaches from teacher-centered to student-centered for three science teachers involved in action research projects informed by transformative learning theory. Additionally, one recent dissertation research (Hendershot, 2010) guided by Mezirow's theoretical lens drew on case study methodology to examine undergraduate students' perceptions of their global citizen identity development within the context of a program that facilitated self-reflection and transformative learning.

The present research is a multiple case study of a professional development program that employed engagement in reflection and dialogue about teaching as ways to promote transformative learning about student-centered teaching. The concept that binds the cases together is transformative learning, which was facilitated by means of reflection and dialogue throughout the professional development program. More specifically, this study is considered to have a holistic multiple case design, as described by Yin (2009), where the unit of analysis for each case study was defined to be an individual science instructor. Hence, it consists of three case studies that collectively examined instructors' transformations of teaching conceptions, approaches, and behaviors while engaged in the professional development program. The three cases were not considered a convenience sample, but rather literal replications, and were examined for similar results. The primary

focus of this multicase study was the characterization of the professional development program in different contexts, namely with science instructors that taught different science subjects and had different levels of teaching experience. Moreover, another task of this type of research is to explore how the different contexts may influence the program (Stake, 2006).

Limitations of Multiple Case Study Methodology

While the greatest advantage of conducting a case study is its depth, Ary, Cheser Jacobs, and Sorensen (2010) argue that this procedural approach inevitably lacks breadth. The dynamics of one social unit, such as the professional development program, may bear little relationship to the dynamics of other similar programs. However, some researchers contend that what is learned from a particular case study may be subsequently transferred to similar social units, in a matter that depends on how future researchers apply present findings to their particular contexts. Moreover, opportunities for insights in a case study may become opportunities for subjectivity or even prejudice (Ary, Cheser Jacobs and Sorensen, 2010). For example, preconceptions of the investigator can determine which behaviors are observed and which are ignored, as well as the way in which observations are interpreted. To minimize the effects due to the researcher's bias, a detailed explanation of the researcher's role in the study and her self-analysis in the context of performing the present study, are included later in this chapter.

Context of the Study

In general terms, the context in which this multiple case study was conducted refers to the environment, interactions, and activities facilitated by participation in the professional development program. This included participation in the workshop and the post-workshop activities conducted on a large public university campus in the southeastern part of the United States. Additionally, for each particular case represented

by an individual science instructor, the term 'context' included the participant's area of expertise, teaching of a particular science subject, and his/her levels of teaching experience. These individual characteristics have been shown by scholars in the field to have a major importance on the extent of engagement in transformative learning about teaching (Kreber, 2006b; Kreber and Castleden, 2009). For example, differences in disciplinary cultures and values can be reflected in different levels of academics' engagement in instrumental, communicative and emancipatory learning about teaching. To this end, it is known that there are clear relationships between academics' epistemologies and their teaching beliefs (Lindblom-Ylanne, Trigwell, Nevgi and Ashwin, 2006; Prosser et al., 2005). More specifically, pertaining to the context of each individual case included in this study, Kreber and Castleden (2009) demonstrated that academics from the hard sciences (e.g., physics, chemistry) tend to engage only minimally in critical reflection on teaching. Additionally, they showed that development of expertise in teaching enhances the potential for improved teaching practice, where teaching expertise involves a higher disposition towards critical reflection.

This chapter begins with a description of the large context of the professional development program, in which the current research has taken place, and then continues by describing the context of each individual case study. The latter takes the form of a detailed description of each partaker in the research and is included in the section on study participants. As characteristics of each individual case influence the particular case study, they will also carry important relevance when performing the cross-case analysis.

The Professional Development Program

Workshops and short-duration courses centered on training faculty on specific new instructional techniques represented the most frequent type of professional development in higher education over the past four decades. It has been shown by several researchers (Henderson, Finkelstein and Beach, 2010; Sunal et al., 2001; Weimer and Lenze, 1997) that these faculty development initiatives that focus on teaching enrichment solely through acquiring or improving techniques or skills, usually culminate in superficial and temporary change. Thus, based on previous research, the author

hypothesized that such initiatives that instead presented new teaching approaches and continued to involve academics in critical examination of their teaching by engaging them in long-term transformative learning processes, would lead to profound changes in their teaching conceptions, approaches and behaviors.

The context of this study was represented by the professional development program, which consisted of a two-day workshop followed by post-workshop activities, and extended over nearly one academic year, from July, 2009 to June, 2010. The two-day workshop took place July 14-15, 2009. Hence, the post-workshop activities stretched for two semesters after the workshop and consisted of approximately twenty additional hours. The overarching theme of the professional development program was to assist college science faculty in adopting learner-centered teaching approaches in their large courses.

Following the aforementioned considerations, the design of the professional development program was entirely based on transformative learning theory. Consequently, the purpose of the program was to assist academics to become aware that there was a need for transformation and unlearning of their previous ways of teaching by examining their old views, perceptions and experiences. As such, during the workshop, all workshop mediators, including the researcher, and then the researcher during the post-workshop activities, engaged in actions that aimed to facilitate transformative learning. These followed the four quadrants of a circle, as indicated by Apte (2009): 1) confirming and interrupting of current frames of reference, 2) working with triggers for transformative learning, 3) acknowledging a time of retreat or dormancy, and 4) developing the new perspective.

The two-day workshop was initiated, designed, and facilitated by the Teaching and Learning Center at the University as a part of their student retention efforts started during the summer of 2009. The overall learning objectives of the workshop consisted of promoting 1) better understanding of the characteristics and motivations of the students, 2) knowledge of the students' various learning styles, 3) knowledge of verbal and non-verbal presentation skills employed when teaching large classes, 4) knowledge of specific student-centered pedagogical techniques successful in large science courses, 5) enhanced

abilities to engage students in their learning process within large science courses, and 6) skills necessary to undertake the redesign of a large-enrollment science course for the incorporation of student-centered teaching strategies. For more details on workshop organization, see Appendix A for an outline of the workshop sessions.

The design of the two-day workshop took into consideration the research findings reported by Gravett and Peterson (2009), which showed that interaction of theory, modeling practice, and reflection experienced in a teaching enrichment program may serve as powerful resources on which to draw when implementing a new teaching methodology. Consequently, active learning was modeled by way of the workshop pedagogy. Moreover, as suggested by Apte (2009), the researcher played the role of *empathic provocateur,* tuning in to participants' current frames of reference. This was done by meeting with the participants prior to the workshop to discuss with them about their experiences on teaching large courses, and asking for written reflections about teaching a large-enrollment course to bring with them to the workshop. The researcher's intention was to gently create a dilemma in participants' perspectives through the presentation of data on student attrition rates in large introductory science courses. As such, during the initial sessions of the workshop, instructors completed a learning style inventory (Felder, 1993) and results were compared among workshop participants and with students' learning styles reported in the literature (Felder and Brent, 2004a, 2004b). This was done to illustrate the multitude of learning styles that can be encountered in a large course and to motivate the effectiveness of employing various teaching techniques that promote active learning. Overall, throughout the workshop, instructors were encouraged to face up to discrepancies between what they think goes on in their large classes and how students perceive these courses. For example, the workshop had one session dedicated to the student perspective on college education in general, and on the learning environment in large introductory courses in particular.

During the two-day workshop, the researcher played an active role, being one of the central facilitators of the workshop. She was mainly involved in the presentation of sessions that focused on student-centered teaching strategies by outlining the technical steps required to implement them and ways to align these pedagogical approaches with

student learning outcomes and assessment techniques. Each active learning strategy was presented by employing relevant examples taken from the literature and actively involved workshop participants. Overall, the workshop facilitators modeled student-centered approaches to teaching. They actively engaged workshop participants in discussions about these active learning strategies and encouraged interaction among workshop participants by facilitating exchanges in opinions concerning implementation of specific active learning strategies in the large courses they teach. Interaction and exchange of ideas among participants was stimulated by the facilitators, thereby creating a community of learners, in this case, learners of new teaching strategies.

During two academic semesters (Fall 2009 and Spring 2010) subsequent to the workshop, the program facilitated learning about student-centered teaching by following directions suggested by Apte (2009), which mainly consisted of working with triggers for transformative learning. Namely, this involved a close contact between the researcher and study participants during which the researcher was allowed to videotape at least three of the participants' teaching sessions of large science courses. The teaching videotapes were shared with the participants and were used to trigger academics' self-reflection about their enactment of student-centered teaching in large courses. These videotapes were also used by the researcher as starting points for engaging in reflective dialogue with the participants on various aspects about their teaching. Following the research performed by Lebak and Tinsley (2010) with science teachers, the researcher made use of the teaching videotapes to broaden possibilities for reflection, to identify meaningful goals for instructional improvement, and to develop action plans for the implementation of more student-centered teaching strategies learned in the workshop. Thus, each new video was intended to begin another reflection cycle leading to the achievement of more sophisticated student-centered teaching (see Figure 4 in Appendix B).

Taylor (2007) has long contended the use of video as a creative approach to stimulating reflection, by providing a mutual visual context for both the participant and the researcher, and thereby promoting a more collaborative research experience. He has argued for the continuous exploration of these research tools under the transformative learning framework. For instance, many studies have used video recordings to stimulate

recall during interviews (Liimatainen, Poskiparta, Karhila and Sjogren, 2001; McAlpine and Weston, 2000; Taylor, 2002), or to induce changes in college teaching (Seldin, 2008).

Relevant for the organization of the post-workshop activities during the course of this study, is that video recordings of teaching have been shown in the literature to function as triggers for engagement in individual and collaborative reflection on teaching (Borko, Jacobs, Eiteljorg and Pittman, 2008; Breyfogle, 2005; Bryan and Recesso, 2006; Lebak and Tinsley, 2010; Sherin and van Es, 2009; Stockero, 2008; Tinsley and Lebak, 2009; Welsch and Devlin, 2006). These studies found that videos of teaching represent the most complete conveyance of a teacher's classroom performance and also provided opportunities for the teachers to view and reflect upon the whole picture of practice, including instructional strategies, levels of student engagement, and student achievement of learning objectives. Thus, the teaching videotape was employed in the post-workshop part of the program "as an object of reflection, a touchstone for insight, and a reference point for witnessing development" (Lebak and Tinsley, 2010, p. 969) during each reflection cycle.

Study Participants

As Stake (2006) suggests, a sample of all cases involved in the *quintain* was obtained. Eighteen science faculty who teach large courses participated in the workshop and were invited by the researcher to participate in the program (i.e., to continue to be involved in post-workshop activities). Three of the workshop participants agreed to be part of the present research, and each represents one case. Thus, each case study is designated the name of the participant that represents the unit of analysis (pseudonyms are used for protection of participants). For ethical considerations, procedures to recruit the participants and conduct the present research were submitted to the Institutional Review Board at the University. Following acceptance of the research proposal, the researcher followed strictly the ethical guidelines set by the Institutional Review Board.

As Merriam (2004) proposed, to engage in transformative learning, people need to possess a certain level of education and hence, to have reached a fairly high cognitive developmental level. For the purpose of the present study, participants were academics who held doctorates and were expert researchers in their fields and hence, met Merriam's criteria to be included in a program based on tenets from the transformative learning theory. Adrian was an Anthropology academic with the status of full professor and who had other administrative functions in his department. At the time of entry in the program, he had been teaching large classes for thirteen years. John was a Chemistry academic with the status of full professor and who also had other administrative responsibilities within the College of Arts and Sciences. At the time of entry in the program, he had not previously taught a large course. Siobhan was a Physics academic with the status of assistant professor (tenure-track) and who had no other administrative duties. At the time of entry in the program, she had been teaching large courses for two academic semesters.

The Role of the Researcher

Stake (2006) suggests that multiple case studies are very complex and that is why they need to be done by one person, especially in the case of dissertation research. Nevertheless, because qualitative methodology is interpretative research involving the inquirer in a sustained and intensive experience with the participants, it introduces a range of strategic, ethical, and personal issues into the research process (Creswell, 2009). Having these concerns in mind, it is imperative for the validity of this study, to explicitly identify the researcher's biases, values, and personal background, that may shape interpretations formed during this study. As suggested by Creswell (2009), this section includes information pertaining to associated ethical issues and methods of gaining entry to the research site, due to the fact that these are elements connected to the researcher's role.

The author followed recommendations by qualitative scholars who argue that "Qualitative understanding of cases requires experiencing the activity of the case as it occurs in its contexts and in its particular situation" (Stake, 2006, p. 2). As such, the role of the researcher throughout this study was that of a participant observer, a technique that has been extensively used in anthropological case studies of cultural or social groups (Yin, 2009). To this end, several research articles that used case study methodology in which the researcher assumed the role of participant observer are reported in the literature; for instance, one involving action research of pre-service science teachers (Kang, 2007), and one focused on a professional development program for teachers (Gilrane, Roberts and Russell, 2008). The researcher assumed a variety of active roles while participating in the program being studied and her role was known to the participants in the study. For comparison, when collecting data from interviews, documents, or passive observations of events, the sources of evidence are in general stable, precise, or embedded in the context they are observed. On the other hand, during participatory observation, such as discussions with study participants about their reflections initiated by watching videotapes of teaching, the investigator gained access to events that were otherwise inaccessible. In this case, the reality was perceived from an insider's viewpoint rather than external to it, leading to insightful explorations into interpersonal behavior. Particularly, one limitation of this multicase study is represented by the third person narrative employed herewith. Nonetheless, this style has been widely used in science education publications (Avraamidou and Osborne, 2009).

More specifically, the role of the researcher throughout this study was perceived by the participants to be that of a representative of the University Teaching and Learning Center. Study participants had the opportunity to interact with the researcher prior to and during the workshop, due to the fact that the researcher assumed a pivotal role in the organization of the workshop and an active role as one of the workshop facilitators. During the post-workshop part of the program, the researcher constantly maintained close interaction with study participants by initiating their participation in reflective activities as prompted by watching videos of their teaching, engaged in discussions with them regarding their teaching behaviors, and offered support for the implementation of student-

centered strategies learned in the workshop. Throughout the study, the researcher maintained a research journal in which she recorded field notes during and after her encounters with each participant in the study. Thus, the researcher had an active role in maintaining the engagement of study participants in reflective cycles stimulated by teaching videos (see Figure 4 in Appendix B).

Additionally, the researcher had been teaching undergraduate science courses at a different higher education institution, where the researcher constantly employed active learning strategies, although in the context of small classes. As a result, the biases brought to the study by the researcher were that postsecondary science learning could not be a passive process and that active, inquiry-based teaching was the most conducive to learning of science concepts.

Data Sources and Data Collection Procedures

The theoretical propositions that led this multiple case study, derived from the transformative learning theory and reflected in the research questions, shaped the data collection plan and the consequent data analysis strategy. Multiple sources of evidence were used in this study, to allow the convergence of different lines of evidence.

In order to follow participants' transformations of teaching conceptions, approaches, and behaviors throughout the duration of the program, this study was divided into three distinct stages: 1) the pre-program stage, 2) the program stage, and 3) the post-program stage. For each case included in the study, the investigator collected data from the sources outlined in Appendix C. A detailed description of each stage of the study and the corresponding data sources and collection procedures, are described below.

The Pre-Program Stage

Prior to the workshop, the researcher asked for permission to meet with each workshop participant at their convenience. Many workshop participants agreed to meet

with the researcher to discuss the upcoming workshop, and among them, all participants in this study. The informal pre-program encounters between the researcher and each study participant consisted of a 30-minute open ended discussion that took place in each participant's office on the University campus. Appendix D contains the seven general guiding questions used by the researcher during this informal conversation with the participants. During the meeting, the researcher described in general the structure and goals of the upcoming workshop and of the research study. The researcher ended each informal meeting with the question "Is there anything else you feel would be helpful for you to know about the workshop?" Additionally, it was at the time of these pre-program meetings that the researcher invited science instructors to participate in the study. These informal meetings were not audio or video recorded. However, the investigator recorded post factum notes about each meeting (Pre-Notes).

The purpose of these informal pre-program meetings with individual participants was to make more information about the workshop readily available to the participants, to allow them to ask questions about the workshop, to create an environment based on trust and openness, and to allow for a close contact between the researcher and program participants. Towards the end of the meeting, participants were asked to provide a one-page reflection on teaching large courses (Reflection), a statement of teaching philosophy (Philosophy), and syllabi for their large courses (Syllabus). These data sources were handed to the researcher at the start of the workshop.

The reason for collecting these pre-program artifacts was that information from these sources served as indicators of the participants' beliefs and teaching practices prior to attending the program, and hence informed the first two research questions. The data collected during this stage were considered free of bias from participants' involvement in the program. Data sources employed during this stage of the study are outlined in Appendix C. To summarize, in order to monitor any changes in participants' beliefs and approaches to teaching that may take place as a result of participating in the program, the following data sources were collected from participants at this stage:

1) Notes taken by the researcher after meeting informally with each participant prior to the workshop (Pre-Notes);

2) Participants' large-enrollment course syllabi for the large enrollment courses taught prior to attending the program (Syllabus);

3) Participants' statements of teaching philosophy (Philosophy);

4) Participants' one-page reflection notes about teaching a large course (Reflection).

In particular, all these data sources provided information about how participants viewed their role as instructors of large-enrollment courses, how they thought students learned, about what challenges they encountered when teaching a large course, the type of learning environment they created, whether they used student-centered teaching strategies, and if they were willing to change anything about this course in a near future. For instance, as articulated elsewhere (Gravett, 2004), written reflections and statements of teaching philosophies can be used as ways of articulating participants' points of view about being instructors of large-enrollment courses, and as starting points for teaching development initiatives. In turn, teaching development activities have the potential to build on these reflections and bring into critical awareness, challenge, discuss and assess academics' practical theories of teaching with the purpose of constructing new knowledge about teaching (Gravett, 2004). Moreover, for the written reflections, "the written format potentially strengthens the analytic capability of transformative learning" (Taylor, 2007, p. 182).

There are reports in the literature that statements of teaching philosophy can be used as data sources for the analysis of academics' beliefs about teaching (Fitzmaurice, 2008; Rossetti and Fox, 2009). More specifically, following the transformative learning theory, Kreber (2006b) analyzed academics' teaching portfolios in search for indicators of reflection on teaching, as ways to document the reflective processes associated with the development of SoTL.

The Program Stage

This stage of approximately one academic year in length (2009-2010), included the workshop offered on July 14 and 15, 2009. After the two-day summer workshop, the researcher videotaped at least three course sessions for each participant and maintained close contact with each of them via e-mail, phone, and personal encounters at their

convenience. The post-workshop activities comprised approximately twenty contact hours between the researcher and each participant. As previously reported in the description of the program, the investigator engaged participants in reflective cycles stimulated by watching of teaching videotapes, as mentioned previously. Individual encounters between the researcher and participants subsequent to participants' self-analysis of videotaped course sessions, focused on the examination of the observed teaching practices, thereby providing participants with opportunities for professional growth through dialogue and self-reflection. The researcher kept field notes during each encounter with the participants (Post-Notes).

Shortly after the beginning of the academic year 2009-2010, a semi-structured interview was conducted and audio-recorded (Initial Interview). Appendix E contains the outline of the initial interview. The questions included in this initial interview were modeled after the questions included in the Approaches to Teaching Inventory (ATI; Trigwell and Prosser, 2004) and explored participants' qualitatively different approaches to teaching before their engagement in reflective cycles triggered by watching videotapes of teaching. Instead of simply completing the ATI, participants were asked questions modeled after items in the ATI, with the goal of allowing for more elaborate answers that have the potential to provide more information to each case study. Specifically, questions included in this interview and modeled after ATI questions, explored participants' considerations about course relevance, structure, pedagogy, and assessment, students' prior knowledge, and ways to facilitate student-student and student-teacher interactions in large courses.

The ATI was developed by Trigwell and Prosser (2004) from research that employed a relational perspective, in which approaches to teaching were seen as contextual or relational. As such, an approach adopted by an instructor in one context may be different from the approach adopted by the same instructor in a different context. Therefore, participants were specifically asked at the beginning of the interview to describe their teaching context. This was intended to evoke participants' ideas and impressions about their teaching in the context of their large-enrollment class. Additional questions were included in the initial interview in order to explore participants' beliefs

regarding teaching large-enrollment courses and their role as instructors. Subsequently, each initial interview was transcribed verbatim and transcripts were shared with each study participant for confirmation of the understanding of the true meaning of his/her answers.

Desimone (2009) contended that, to elicit reliable and valid measures of teachers' overall instruction, at least three teaching observations are required for an extended period of time. Consequently, at least three teaching sessions were videotaped by the researcher within each case, during the course of this stage. The purpose of video recording these course sessions were twofold: 1) to provide an opportunity for participants to review and analyze their own teaching practices, and therefore be able to observe themselves, reflect on their actions, and in turn, change their teaching approaches, if needed (Borko, Jacobs, Eiteljorg and Pittman, 2008; Breyfogle, 2005; Bryan and Recesso, 2006; Lebak and Tinsley, 2010; Sherin and van Es, 2009; Stockero, 2008; Tinsley and Lebak, 2009; Welsch and Devlin, 2006), and 2) for videotapes to be used as data sources for the analysis of participants' teaching behaviors throughout the program. Each videotaped course session was transcribed verbatim (Video).

Observation of teaching is often heralded as the most unbiased form of data collection, removing the self-report bias of interviews and allowing a clear look into what is actually occurring in the classroom, as the teacher implements new teaching (Desimone, 2009). Observations can make fine distinctions in teaching practice that interviews or self-report surveys cannot make. Accordingly, researcher's observation notes were interspersed throughout the transcripts of the videotapes, in order to complement these for any loss of information pertaining to participants' teaching behaviors, student-teacher and student-student interactions, or classroom environment.

Videotapes of teaching sessions were evaluated by the researcher in terms of the extent to which participants' teaching incorporated student-centered, active learning practices. For this purpose, the Reformed Teaching Observation Protocol (RTOP) was employed. The RTOP is an observational instrument, designed to qualitatively evaluate instruction (Sawada et al., 2000). It was previously used to evaluate instruction in college science classrooms (Campbell, Oh, Shin and Zhang, 2010; Lawson et al., 2002). With

relevance to this study, RTOP was reported in the literature as a catalyst for self-reflective change toward student-centered teaching, when used by instructors to score their own instructional strategies (MacIsaac, Sawada and Falconer, 2001). Hence, each videotaped course session was rated for the 25 RTOP items, which refer to the extent to which student-centered teaching methods (e.g., teaching through active learning), are incorporated in instructional practice. Each RTOP item can be given a score between 0 and 4. Therefore, the maximum RTOP score is 100 points. Information about the reliability and validity of RTOP and results of an exploratory factor analysis were initially reported by Piburn and Sawada (2000). Appendix F contains the RTOP.

The RTOP scores of each videotaped teaching session were used as indicators of the extent of student-centered instructional methods employed in each case. These scores did not carry quantitative significance. Rather, they were used to monitor participants' transformations of teaching practices on the teacher-centered to student-centered continuum, from lower RTOP scores, which indicated enactment of more teacher-centered behaviors, to higher RTOP scores, which reflected a higher degree of student-centered practices. Prior to perform the present study, the researcher undertook the RTOP training available on-line from Buffalo State University of New York (AZTEC, 2007), on how to use it to evaluate student-centered teaching (RTOP).

To facilitate triangulation of the information collected from interviews, researcher's notes during meetings with participants, videotaped course sessions and their associated RTOP scores, syllabi of the large-enrollment courses taught after attending the workshop (academic year 2009-2010) were collected from each participant. Other teaching artifacts (e.g., study guides, course hand-outs) were also collected by the researcher (Teaching Artifact).

The reason for collecting these program-related data sources is that they can serve as indicators of participants' beliefs and teaching behaviors developed during their participation in the program, and hence provide information for the last two research questions. To summarize, the following data sources collected from participants at stage two and outlined in Appendix C were:

1) Verbatim transcriptions of the initial interview (Initial Interview);

2) Notes taken by the researcher during individual meetings with participants (Post-Notes);

3) Verbatim transcripts of videotapes of course sessions, which include observer's field notes (Video);

4) RTOP scores of videotaped course sessions (RTOP);

5) Participants' course syllabi for the large-enrollment course(s) taught during the academic year 2009-2010 (Syllabus);

6) Other teaching artifacts (Teaching Artifact).

The Post-Program Stage

After the conclusion of the academic year 2009-2010, the second open-ended interview was conducted and audio recorded (Final Interview), in order to determine whether participants changed their teaching approaches throughout their participation in the program. Appendix G contains the outline of the semi-structured final interview. The final interview contained similar questions to the ones included in the initial interview and were modeled after the questions included in the ATI (Trigwell and Prosser, 2004). Subsequently, each final interview was transcribed verbatim and transcripts were shared with each study participant for confirmation of the understanding of the true meaning of his/her answers.

As suggested by Eley (2006), approaches to teaching revealed from semi-structured interviews adapted from the ATI, may be considered as outcomes of academics' reflections about teaching. Besides similar questions included in the initial interview that explored participants' considerations about course pedagogy and assessment, students' prior knowledge, and ways to facilitate student-student and student-teacher interactions in large courses, additional questions were included. These additional items aimed to investigate participants' opinions about the program in general, and more specifically, their engagement in reflection and dialogue about teaching, triggered by watching of teaching videotapes. A comparison between participants' answers to questions in the initial and final interviews had the purpose of revealing participants'

different approaches to teaching between the study stages that correspond to the time prior to and after becoming engaged in reflection and dialogue about teaching.

In order to obtain a clear image of the participants' involvement in scientific research (scholarship of discovery) or other university duties, the most recent *resume* (Resume) was requested from each participant before the completion of the study. Information obtained from this data source was intended to give an indication about the time constraints or any other factors that could interfere with participants' teaching commitments. The researcher's hypothesis was that participants intensely involved in research, as documented by recent records of publications or awards of research grants, would be able to dedicate less efforts to the teaching endeavor, fact mirrored in their teaching practices.

The reason for collecting these data sources was that they can serve as indicators of participants' beliefs and teaching behaviors developed during their participation in the program, and hence provide information for the last two research questions. To summarize, the following data sources were collected from participants at this stage and are outlined in Appendix C:

1) Verbatim transcriptions of the final interview (Final Interview);
2) Participants' updated resumes (Resume).

Data Analysis

This multicase research included three individual case studies (Adrian, John, and Siobhan) for which data were examined to answer the following three research questions:

1) What are participants' conceptions about teaching large science courses?
2) How do participants' teaching approaches transform after engaging in reflection and dialogue on their teaching?
3) To what extent are these transformations reflected in their teaching practices?

Considerations extracted from the transformative learning theory (Mezirow, 1981, 1990, 1991, 2000, 2009) were followed throughout the design of the study and the formulation of the research questions and consequently, were reflected in the data collection plan and the process of data analysis. Because the overall aim of qualitative analysis is to organize, synthesize, provide structure to, and elicit meaning from research data, the underlying theoretical framework was used to create codes, then group them into categories, and subsequently, to derive the main themes during the data analysis process. Appendix H contains an outline of the data sources employed to answer each research question. Each case consisted of two types of data: textual data from participants' documents and transcripts, and RTOP scores.

For each case study, in analyzing the textual raw data (transcripts of interviews and videotaped course sessions, field notes, statements of teaching philosophy, reflections), the researcher looked for units of meaning (codes) to form the basis for the development of categories and themes. In order to enable an analysis that directly answered the research questions, the coding process was shaped by these questions and influenced by the underlying theoretical framework of the study. In essence, the constant comparative method of data analysis was employed, which combined inductive coding with simultaneous comparison of all units of meaning obtained. All textual data were coded manually using differently colored highlighters. A color coded scheme was used indicating how colors connected with categories. As suggested by Saldana (2010), after performing two cycles of coding, the investigator examined each final code to determine its distinctive characteristics. Subsequently, by looking for patterns - similarity and correspondence - among codes, the researcher included related codes into the same category. Categories were refined through several iterations throughout the analysis process. The importance of each category was established by looking at the frequency with which codes within a category occurred. Each category was examined for internal consistency and distinctness from other categories. After the categories have been refined, the researcher explored the relationships or patterns across categories, identifying the major themes. This process of coding, categorizing, and developing themes was

repeated for each unit and set of data. Finally, the integration of data into themes yielded an understanding of each case studied.

Other textual data are represented by course syllabi, course artifacts, and participants' updated resumes. Course syllabi and teaching artifacts were examined as a whole, to evaluate the degree of incorporation of student-centered teaching principles in the overall course structure. For example, these documents were inspected for the inclusion of service or problem-based learning. Also, in order to evaluate the role of the workshop on participants' course organization as reflected in the course syllabus, course syllabi from before and after the workshop were compared for the identification of changes assumed as a result of participation in the workshop. Participants' updated resumes were scrutinized for any scholarly activity performed throughout the academic year 2009-2010, while they were involved in this study. Any scholarly activity reported, such as publication in peer-reviewed journals or granting of a research award, was regarded as an interfering factor with the implementation of new teaching strategies. Moreover, adhering to findings from previous seminal research in the field (Kreber, 2006b), the updated resumes were scrutinized for the identification of indicators of engagement in the reflective processes underlying the development of the scholarship of teaching and learning. For instance, presenting findings from classroom teaching experiments at teaching-related conferences, or publishing articles about one's classroom research, are considered clear indicators of engagement in transformative learning about teaching (Kreber, 2006b).

In order to monitor the extent of incorporation of student-centered teaching methods, each videotaped course session was scored by using the RTOP teaching observation instrument (AZTEC, 2007). For each case, transformations of participants' teaching behaviors were evaluated through a comparison of the RTOP scores from each videotaped teaching session. Thus, an increase of the RTOP scores from the beginning toward the end of participation in the program was considered an indicator of increased use of student-centered teaching methods. Nevertheless, interpretation of RTOP scores was performed in the large context of each case, and corroborated with information from other data sources.

Construction of the Case Studies

In order to identify participants' conceptions about teaching large courses at the time of their entry into the study, participants' coded reflections (Reflection) about teaching large courses and coded statements of teaching philosophy (Philosophy) were triangulated with coded field notes provided by the researcher after meeting with each participant before the workshop (Pre-Notes). Findings from these data sources were triangulated with information gathered from the analysis of participants' course syllabi (pre-workshop Syllabus).

Interview data served as the primary data source for the analysis of participants' teaching approaches. As such, in order to evaluate the transformation of participants' teaching approaches throughout the program, codes and categories from the final and initial interviews were compared. Findings from these data sources were triangulated with coded data from the researcher's field notes (Post-Notes), comparisons of course syllabi before and after the workshop, and participants' updated resumes, for the identification of factors that may influence such transformation.

Finally, to examine how transformations of teaching approaches were reflected in participants' teaching practices, transcripts of video recordings of teaching sessions (Video), which included the researcher's observation notes, served as the primary data source for the analysis of the teaching behaviors. As such, coded transcripts of video recordings were compared and corroborated with corresponding RTOP scores. Findings from these data sources were triangulated with information obtained from the comparison of participants' pre- and post-workshop course syllabi, and teaching artifacts.

Each case was constructed by linking the subcategories and categories emerged from the data with the research questions. After refining and organizing the categories into distinct groups related to the research questions, each group of categories was examined for the emergence of central themes. Consequently, each case was organized as follows: First, an examination of the participant's conceptions about teaching large classes revealed his/her teaching orientation (i.e., teacher- or student-centered) and contributed to the deep understanding of the context of each case. Second, participation

in the program, namely the degree of engagement in reflection and dialogue, and the extent of enactment of new teaching methods, provided valuable information pertaining to the transformation of teaching practices throughout the program. Third, an examination of enacted teaching practices corroborated with an assessment of transformation of teaching approaches, led to the establishment of general conclusions for each case.

Cross-Case Analysis

The cross-case analysis was constructed as informed by Yin (2009). Through the within-case analysis, categories and subcategories were constructed based on descriptive, attribute, *in vivo*, and process codes obtained from each case (Saldana, 2010). A table including all codes from categories and subcategories was created for each individual case (see Appendix I). Findings were then aggregated across the three case studies through a coordinated system. These tables were placed side by side and were examined several times for patterns, or common relationships. The examination of these category/subcategory tables for cross-case relationships relied strongly on argumentative interpretation, not on numeric tallies (Yin, 2009). The analysis of the three tables enabled the researcher to draw cross-case conclusions that led to the emergence of themes. Finally, the cross-case analysis was organized according to the research questions.

Validity and Reliability of the Study

Validation of findings occurred throughout all stages of the study and involved constant checking for the accuracy of the findings from the standpoint of the researcher, study participants, or readers of the final research report (Ary, Cheser Jacobs, and Sorensen, 2010; Creswell, 2009). Credibility of the findings, or internal validity, was strengthened by the use of multiple sources of data, such as interviews, observations, relevant documents, and the use of a combination of different data collection procedures (e.g., use of direct observation of teaching and use of the teaching observation protocol to obtain RTOP scores). Also, at the end of the data collection period, the researcher asked participants to review and critique the verbatim transcripts of interviews and videotape

recordings for accuracy and meaning (member checking). Moreover, while maintaining confidentiality of study participants, a peer debriefer was periodically provided with the raw data along with the investigator's interpretations, in order to identify possible biases and evaluate whether the interpretation was reasonable considering the evidence. Identification of the researcher's own biases was also performed at the beginning of the study and examined constantly throughout. The plausibility of the study, which concerns the degree to which the explanation developed from the study fits the data and is defensible, was ensured through the researcher's extended fieldwork, and pattern matching during data analysis (theoretical adequacy). From the viewpoint of the readers, the credibility of the study was addressed by using many low-inference descriptors, such as verbatim or direct quotations (interpretive adequacy). To summarize, all these methods were used to establish the internal integrity of each case, allowing for relevant cross-case analysis from which to draw conclusions.

The dependability, or trustworthiness of the study, was maintained through triangulation and by examination of the degree of interrater and intrarater agreements. For instance, four additional independent coders coded approximately 20% of the total textual data and results were compared to the transcripts coded by the researcher to calculate the percentage of agreement. The coders were Teacher Education graduate students, three students from Science Education and one from Social Studies Education. All four coders were accustomed to the transformative learning theory and knew the study research questions. A 77% percent agreement was calculated by dividing the number of coding observations that agreed, over the total number of coding observations made by independent coders. Qualitative researchers argue that 75 to 80 percent agreement, or an intercoder correlation of .70 -.80 or higher, is indicative of high reliability (Patton, 2002). Additionally, by performing two cycles of coding, the investigator compared the codes created between the first and second cycles of coding. In order to ensure for a reliable study, the stability and consistency of themes were checked by verifying the correctness of the transcripts, maintaining the accuracy of the definition of codes and categories, and by cross-checking codes developed by the researcher and the independent coders.

Confirmability, or the objectivity of the study, and the neutrality of the investigator, were preserved through the aforementioned methods: triangulation, use of peer debriefers, and reflexivity of the researcher. Transferability of this study was accomplished through the cross-case comparisons and identification of themes, performed during the cross-case analysis (Stake, 1995, 2006; Yin, 2009). Finally, the abovementioned data sources served for the examination of evidence insofar that converging sources were used in building a coherent justification of the emergent themes.

Study Limitations and Assumptions

Based on previous research reviewed in the previous chapter, the researcher assumed that engagement in reflection and dialogue about teaching would have a high likelihood to raise the question of how one teaches and finally, to have a positive effect on the improvement of teaching and hence, the incorporation of student-centered teaching methods.

One important limitation of this study that may influence its transferability, is represented by the fact that the study participants agreed to participate in the study and as such, may have certain dispositions. Another limitation may derive from the researcher assuming the role of a participant observer. This may have led to bias from the manipulation of events by the investigator: For instance, some situations were created due to her active participation. Nevertheless, the researcher assumed this role inherently, due to her active participation in the development and organization of the workshop in the initial stages of the program. Even though one may argue that this introduced a bias to the study, it actually was quintessential in creating the conditions for the researcher to be perceived as a representative of the Teaching and Learning Center for the University. Being perceived as such, enabled her to sustain a positive relationship with study participants in which participants felt confident to discuss their teaching practices, comment about their feelings after watching videotapes, and finally seek advice

concerning implementation of active learning strategies. Nevertheless, the researcher was a graduate student and therefore, her status may have diminished some of her attributes in the course of her relationship with the participants.

CHAPTER IV
RESULTS AND DISCUSSION

The results included in this chapter start with a presentation of the three case studies. Each case study is divided into six sections: Introduction, Conceptions about Teaching Large Classes, Participation in the Program, Influence on Teaching Approaches, Influence on Teaching Practices, and Summary. This is followed by a cross-case analysis of the three cases. The emergent themes were divided into three categories based on their relevance to the three research questions: Conceptions about Teaching Large Classes, Influence of the Program on Teaching Approaches, Influence of the Program on Teaching Practices.

The results in this chapter attempt to answer the three research questions of this study:

1) What are participants' conceptions about teaching large science courses?
2) How do participants' teaching approaches transform after engaging in reflection and dialogue on their teaching?
3) To what extent are these transformations reflected in their teaching practices?

Case One – Adrian

Introduction

Adrian was a professor of Anthropology who had been at his current University for approximately nineteen years and was currently the head of the department, a position he has held since 2000. Adrian was a male in his early fifties. Since 2006, he had not been actively involved in research and scholarship in his field due to other responsibilities and he was not currently directing graduate students. However, he

continued to publish articles in other types of peer-reviewed journals and was an invited speaker at conferences in his field of Biological Anthropology. Thus, his main academic involvement centered on teaching lower and upper level courses and performing administrative duties in his department. Relevant to this study, Adrian was affiliated with the National Center for Science Education, an organization that provides information and resources at local, state, and national levels, for maintaining evolution in public school science education. For example, during the summer of 2009, he submitted an article to their main publication (*Reports of the National Center for Science Education*), which was published in the Fall of 2009. This article reported the misconceptions and persistence of anti-evolutionary ideas for students enrolled in his Anthropology courses. The data collected over ten years originated in a survey designed to estimate how well students understood science and evolution. He had been administering this survey during the first day of class, in both introductory and advanced courses, with the purpose of facilitating in-class conversation about the subject. Additionally, he was invited to present papers on teaching evolution at science education meetings.

Over the years, Adrian had been the recipient of several teaching and advising awards at his university even though he said he had no formal teaching training. Overall, he had twenty years of teaching experience, of which he had taught the large-enrollment Anthropology courses for about thirteen years. Since he had not taught a large-enrollment course since the fall semester of 2002, at the beginning of this study in July 2009, he was starting preparations to teach a large-enrollment Anthropology course scheduled for both semesters of the 2009-2010 academic year.

Conceptions about Teaching Large Classes

As revealed from his reflection, statement of teaching philosophy, and researcher's field notes from meeting with him before the workshop, Adrian's main teaching focus was to show his students the relevance of the field of Anthropology to life in general, "to spark students' interest in the field" by showing his enthusiasm, incorporating personal anecdotes and descriptions of his research experiences, and by conveying the nature of science in his teaching. This was reflected by his teaching

philosophy when he said, “It is often a student's first and only exposure to our field. If we are to see any of these students again in our upper division offerings, I believe that an effective initial course is necessary” (Adrian, Philosophy). According to Adrian’s course syllabus, he approached teaching of the large course in a schematic manner, by including an outline of textbook information, course schedule, grading schemes, and contact details for him and his teaching assistants.

Adrian was very interested in promoting students’ conceptual change and in identifying their misconceptions. He felt that the way to do this in his large-enrollment courses was by questioning the students. He started his first class by administering a survey, which included questions about evolution, creation, and science, as a way of evaluating students’ conceptions about the nature of science in general. After collecting anonymous answers from students, he used these answers to start a discussion about evolution and nature of science, in order to lay the foundation for more specific Anthropology concepts introduced later in the course. He has been using this approach for more than ten years. He said, “I get people talking all over the place, and so it's a wonderful way of exploring these ideas, getting them to acknowledge these pre-conceptions and misunderstandings” (Adrian, Initial Interview).

Before participating in the program, Adrian’s conceptions about teaching large-enrollment courses were mixed. He was concerned that the class would be comprised of a mixture of honors and regular students. He perceived that due to a lack of assistance he might not be able to design tests that included essay type questions and that he would be constrained to multiple choice exams. About this he remarked, “I would prefer to construct exams that have both an objective (multiple choice, usually) and essay component, but I am leery of having to read 250 essays 3 to 4 times a term” (Adrian, Reflection). Adrian was also concerned about student attendance issues. Before participating in the program he expressed that he hoped he would be able to learn effective assessment techniques in the context of large courses and ways to use technology to manage student attendance (author’s personal research journal). When asked how he perceived his role as instructor of a large course, during the researcher’s

initial meeting with him, he said he saw himself as teacher/scholar, but by teacher, he indicated a person who "imparted" knowledge to the students.

As indicated by Kreber (2006b), involvement in certain activities, such as administering inventories to students, gathering feedback from students on their learning of discipline-specific concepts, taking into consideration end of term student evaluations, presenting findings from classroom teaching at teaching-related conferences, and writing articles on how to facilitate learning in the discipline, were considered indicators of engagement in reflective processes underlying the scholarship of teaching and learning. In consequence, based on his participation in such actions, before his involvement in the program, Adrian was regarded as an academic engaged in content and process reflection on instructional and pedagogical knowledge.

Participation in the Program

Adrian's participation in the workshop was very active and, at one point, he volunteered to demonstrate for all partakers how he normally structured a course session. When meeting with him after the workshop, he expressed his enthusiasm when he remarked that the workshop was "an enriching experience". After acknowledging the fact that he had certain inertia when it came to changing his teaching, his overall attitude indicated that he was willing to learn new ways to engage students in the context of a large class, provided the researcher gave him full support. Despite his busy schedule as department head, he made every effort to meet with the investigator, and he agreed to let her videotape his class three times, at his convenience. In consequence, he invited the researcher to videotape his class once during the fall semester of 2009, and twice during the spring semester of 2010. He met with her to discuss his teaching and plan the implementation of new strategies after each videotaped session. To follow the flow of events, Appendix J contains a summary of the outcomes of the engagement in reflective cycles on the transformation of teaching practices.

Adrian first invited the researcher to videotape him to see how he normally taught this class. He mentioned the fact that he last taught this class seven years ago, admitting to "feeling frustrated when (it comes to) teaching a large class". After sharing the first

videotape with him, the author met Adrian to discuss his teaching a couple of months later. Overall, his impression about the videotaped class was positive and his observation was that the class had a logical, coherent flow. The only concrete action that he commented upon was one of his mannerisms, referring to his sarcastic smile. When the investigator inquired about his opinions regarding student engagement and learning environment, he changed the subject and indicated that he was not interested in discussing this aspect of his lesson.

The researcher and Adrian met again two weeks later to plan the implementation of a new teaching method that he had learned during the summer workshop. From the start, he expressed his doubtfulness of his ability to incorporate a new teaching method, mainly due to the lack of class time. After assuring him that active learning would not use much of his class time, the researcher described the peer instruction teaching method (Mazur, 1997) and how another colleague in a different department had implemented this type of active learning by using flashcards. After he listened attentively, he was open to the possibility of "trying it", concluding that he was optimistic of "getting good results" regarding student engagement. He insisted that he needed the researcher's full support for this action and asked her to write him an e-mail outlining the steps of the method. The day before the second videotaped course session, she gave him 300 colored flashcards and sent him an e-mail outlining the implementation steps of the technique.

The researcher videotaped Adrian for the second time when he implemented peer instruction by making use of flashcards to monitor students' responses. After sharing the second videotape with him, they met a couple of months later to discuss his teaching. He had pertinent comments regarding student engagement, noticing that the class overall, was more actively engaged than in the past. However, he disclosed his preconceived ideas about the students who sat in the back of the auditorium, declaring that those students were not interested in the subject matter. More importantly, he had ideas on how to refine the technique in order to offer the students the possibility to explore alternate answers, and had pertinent comments on the technical aspects of its implementation. In the end, he had the initiative to use peer instruction again in his last class for the academic year 2009-2010. The researcher videotaped Adrian's class for the third time

when he implemented peer instruction for the second time. Immediately after the third videotaped course session, the investigator shared the recording with him and they met to discuss about it during the last interview. His overall impression about implementing peer instruction was positive, mentioning that contrary to his beliefs, he was surprised that it was not time consuming.

Influence on Teaching Approaches

During their first interview, Adrian and the researcher talked about his teaching approaches and his perceptions of the workshop. While he indicated that he organized his course around relevant concepts, he did not include clear course objectives and learning goals in the course syllabus. He remarked that, "I'm not sure if I'm explicit about course objectives and learning goals, but I think as I mentioned when I started this course this semester, I did incorporate into that syllabus these large couple questions that we will be addressing in the semester. […] In addition, they can look at the course syllabus, and I'm very explicit about what each day is going to cover" (Adrian, Initial Interview). After the workshop, Adrian's syllabi did include a new section titled 'course objectives' in which he included what he called "the big questions" of the course. In the last interview, when asked how he connected course objectives to teaching approaches, he responded:

> I have those ideas of what I'm trying to convey, if not in a particular lecture, but over a series of lectures, with respect to those big questions. And, I've been doing this long enough that I know to make a thread to connect those lectures. And the big idea that I'm trying to get to, I'm very explicit about, trying to talk about those in those contexts. So, I think that just the instructional lectures, and a focus on what I really want them to understand, allows those big questions to be explicitly addressed and answered in those lectures (Adrian, Final Interview).

Adrian did not connect learning objectives to student understanding or engagement, but instead mainly to the learning of the content itself. Adrian indicated that he did not assume students possessed any prior knowledge regarding the ideas taught in his classes, because his course had no pre-requisites. As such, he assumed his students

had knowledge of high school level Biology, but he did not test this assumption specifically. The only instance when he made use of students' prior knowledge was when he challenged their misconceptions and misunderstanding about science, when he administered the science-evolution survey during the first day of class. His purpose for this survey was to promote students' conceptual change about evolution and related ideas, which he explained further in the course.

> …to dispel some of those misconceptions has a basis for helping them understand what the scientific understanding of evolution is, why it is science, what the difference is between scientific ways of knowing, religious ways of knowing. … this is a great stepping stone for helping them understand and also alleviating some of the, I'm sure, discomfort that some of the perhaps religious students have in that class, about what I'm going to be coming out and talking about and hopefully dispelling the idea that all scientists are these atheistic, anti-religion people. And so that's another important purpose of what I do that first day (Adrian, Initial Interview).

When discussing student evaluation, Adrian considered that assessment was a clear indicator of student effort and could be used to track students' academic progress. The questions included in his tests were spread out to represent an equal distribution of notions presented in class, and were "not tricky". Very importantly, he considered that the types of assessment methods used depended largely on the number of students enrolled in the class. And this reinforced one of his big concerns that he voiced from the beginning, that by not having teaching assistants assigned to his course, he had no help with the grading and hence, he was limited to the multiple choice format for his tests, as he expressed when he said, "I think in large part, the number of students enrolled in the class determines what's available as far as the kinds of grading and types of assignments I can give" (Adrian, Final Interview).

Throughout all discussions the researcher had with Adrian, he was very keen to explain that students were presented with clear expectations from the beginning, referring to the fact that they were given study guides which contained the important course

information on which they would be tested. He said, "…they realize what I think is important. And that helps them organize and reemphasize those terms, concepts, and processes' names that I think are important that they probably should know if they want to succeed on the exam" (Adrian, Initial Interview). From the beginning to the end of the program, Adrian placed the weight of student engagement and student success in the course entirely on the students. This was clear when he said about his students that,

> They have to understand the words. I had one student in here that didn't do well after the first two tests. Came to me after that and said, I missed all the ones that had big words. And I wanted to just shake her. But, if I say a big word, then I expect them, if they don't understand it, to look it up or to ask. […] My impression is that they probably just shouldn't be in college in the first place. That's my guess. They are not putting out the effort. They are not coming to class. They may not be prepared to even understand the material. And my job as university professor is not remediation. I'm not there to tell them what this world means, or how to study, or how to read, or how to prepare for an exam. These are skills that I expect them to have coming into the class. […] I might not be able to reach [all of] them, and if that's the case, too bad. There are other people that probably just don't want to be there. But, I think most of the time, most of the students, if they give me a chance, are going to get interested in the subject matter (Adrian, Final Interview).

He thought that by incorporating his research interests in his lectures, showing his passion and enthusiasm for the subject matter – "being on" – were effective ways to indicate the relevance of the field of Anthropology to his students. Additionally, his impression was that by making eye contact with students close to him, who sat in the front rows, and moving back and forth while he was lecturing, he kept students engaged with the notions he presented to class. He said that he did not, "stay behind the podium, I never stay behind the podium. I can't stand being locked in one place, so I'm always moving. So, they're going to have to track me, if they're going to be - that's one way of being at least involved from a visual perspective" (Adrian, Initial Interview).

Throughout the discussions with the researcher, Adrian's conceptions about attendance were that students had to attend his classes to get excited about the field, to understand the notions presented in class, and to succeed in the course. He did not mandate attendance because he wanted to treat his students as adults capable to commit to the course. After the first test, he identified the students with low grades, invited them for discussions in his office, and offered opportunities for extra credit assignments to improve their grades.

Adrian had preconceived ideas about the students. For instance, where students sat in the auditorium was an indicator for him about the level of the student's interest in the subject matter, and a predictor of success in the class. He considered that students who sat in the back "did not care" and that the ones sitting in the middle and front, with whom he was able to make eye contact easier, were the ones who actively participated in every class and were more likely to do well in the course. He indicated that just a small proportion of students were genuinely interested and engaged, and that the rest of the students were in the class either to get a general education credit, or "did not give a damn". Here he explains further:

> The real is that there are some people out there that will never give a damn, no matter what I say. Now, some of them are the failures I talked about earlier. But, not all of them are. Some don't give a damn, and still skate by with a C or better. And they are just there to get that general education credit. They are just there to get whatever they need for that class to satisfy. […] And then there's the middle percentage, maybe if we're talking about that first group that doesn't give a damn, ten, twenty percent. Maybe there's fifty, sixty, seventy percent of people that occasionally are engaged. Most often are pretty neutral, can take it or leave it. But are there, coming to class, taking notes, and studying when they have to study. Get the grade they think they want to get, or what they are going for, maybe the Bs and the Cs. But, then there are the students that I was almost focusing my lectures upon. And those are the ones that are engaged that sit up front, sit in the middle, ask questions, answer

> questions, are looking at me when I'm talking at them, and seem to be with it. So they are the ones that keep me going back. I don't think I'm ever going to get to the first group I described, the ones that don't give a damn. The middle group, sometimes they are into it, other times they are not, and that might happen. But, if I can keep that other ten, fifteen, twenty percent engaged that are there to really learn and enjoy, and be excited about it, that's the only thing I can do (Adrian, Final Interview).

Adrian's perception about his interactions with the students during the class was that through constantly questioning students, he established an interactive learning environment conducive to promoting students' engagement. He acknowledged the students' number, class time, and classroom seating scheme, as major constraints for actively engaging the majority of the students in the large class. He mentioned that the same students, mainly those seated in the front, were the ones that answered his questions regularly, a fact that he felt he was not able to change. When asked about the promotion of critical thinking skills through these questions, he suggested that at the introductory level students needed to know information, and that only at upper levels were they required to think more critically. Moreover, he indicated that when asking certain important questions, students had to fill information in a sort of puzzle, based on previous course material, and that he led the students to the right answers. He motivated his strategy on the basis of the complexity of the course and that he felt that students needed a structured approach. When asked about debates, he said that he did not do them because they were very time consuming.

Adrian said that he was an effective teacher because he constantly conveyed his enthusiasm for subject matter, demonstrated its relevance by focusing on the big picture, and made use of humor in all his lectures. Throughout the study, he maintained that teaching a large course posed major constraints on his teaching approaches, mainly due to the number of students, the long time gap from when he last taught a large course, the lack of a separate discussion session led by teaching assistants, and lack of help with grading tests.

Overall, Adrian believed that teaching was a noble calling, a “serious thing”. He loved teaching and he exclaimed, “I'm never going to want to not teach”. He perceived himself as an experienced, knowledgeable teacher, particularly a teacher scholar, whose growth as a teacher was mainly achieved through experience. Overall, he believed that his role in the large introductory class was that of a conveyor of knowledge, an impression that he did not change throughout the study.

Regarding the transformation of teaching practices with the purpose of engaging more students in his large classes, he revealed throughout the study several contradictory stances. For instance, while he showed from the beginning a willingness to learn about teaching and learning in general, and about new teaching methodologies in particular, he also acknowledged being skeptical about active learning, such as when he commented, “I'm not convinced they'll learn it by talking to one another, by learning it from each other”. However, the researcher persuaded him to try using peer instruction, and after the fact he seemed positively impressed with the increased active participation of students. While Adrian was pleasantly surprised to learn that peer instruction did not take him an extended period of class time, as he was expecting, he was skeptical that students’ discussions during the peer instruction exercise focused on the question he posed in class.

Despite receiving the investigator’s full support and detailed information throughout the program about the reported effectiveness of these new methods in large classes, and contrary to his impression after using peer instruction several times, he attributed his minimal transformation of teaching practices throughout the program, to the large number of students in the class and to the limited class time. At the end of the program, he admitted clearly his skepticism regarding the effectiveness of actively engaging students through peer instruction when he remarked:

> So, if the intent was to get people involved and participating that didn't normally do so, I'm not sure if it was successful. But, it still broke it up a little bit, made it perhaps a little different for the students, at least after the first couple times, and maybe got some of them, that maybe if they weren't going to be comfortable answering the question out loud for the class,

perhaps they did get something out of it by talking to their peers and trying to answer the questions (Adrian, Final Interview).

During the last interview, Adrian revealed his opinions about his participation in the program. He thought that the workshop was "an enriching experience" through which he learned new teaching methods. Very importantly, he learned in the workshop about the importance of communicating to students the course objectives and their learning goals. As a result, to convey the course relevance, he introduced a new section for course objectives in his syllabi. Referring to his dialogue with the researcher, he indicated that discussing about his teaching on the basis of watching himself in the process of teaching, made him think about the act of teaching more explicitly. After concentrating initially on his mannerisms, watching himself in the act of teaching prompted him to pay more attention to student engagement and to draw enjoyment from observing how students interacted with him and among them. As such, he had pertinent suggestions to improve the method in order to maximize student engagement and to enhance its technical aspects. Applying his own modifications stimulated him to continue to use the method and to examine the effects in the classroom. After watching the three videotapes, his remarks indicated that he observed the same students that normally engaged with his questions actively participated in the peer instruction exercises. This may derive from his preconceived ideas about students and skepticism toward the effectiveness of the new method. Finally, Adrian's opinion about watching his teaching videotapes was that they did not bring him new information about his teaching and student engagement in his class. He said regarding impacting his future teaching that he was, "not sure if they have a direct impact on future lectures. I think they were validating what I perceived as to what I was doing in the first place" (Adrian, Final Interview).

Overall, the program prompted Adrian's focus on teaching and learning in general and on students' in-class interactions in particular. Although it shaped his enactment of student-centered teaching during the study, the program did not influence Adrian's core teaching beliefs or the incorporation of these practices in his future teaching.

Adrian had thoughtful ideas about similar future programs organized with the purpose of enriching academics' teaching practices. He considered that similar programs

organized for new faculty and having senior faculty as moderators, would create a productive atmosphere in which learning would occur among peers. He suggested that a cross-disciplinary approach would bring faculty members from various disciplines, thereby generating a diverse environment conducive to learning about teaching.

Influence on Teaching Practices

Adrian was videotaped three times during the program and his teaching practices were analyzed and then evaluated by using the RTOP. Appendix J contains a summary of the outcomes of his engagement in reflective cycles on the transformation of teaching practices.

For the first videotaped class, Adrian asked the researcher to observe a representative course session. The class had a very fast pace and he did not use any student-centered teaching strategies. His teaching practices comprised mainly conveying of information, asking rhetorical questions, and questioning students. He lectured for the majority of time while pacing back and forth in front of the auditorium. He did not attempt to go up and down the aisles to maximize contact with students. Even though he posed many rhetorical questions, he devoted some time to questioning students, but he did not allow the students sufficient time to respond. Students who were quick to answer and who were closer to him, in the front part of the auditorium, managed to engage minimally in short discussions with him. When alternative answers were given, he did not explore them, but explained the facts and then moved to the next notion. There was absolutely no communicative interaction among students. He stopped at certain time intervals to ask for students' feedback, or their questions about the material. While students had one or two questions, overall he moved on very fast and he did not create ample opportunities for students to bring questions to him. He made use of technology, by projecting maps, images, and charts, which he used in his explanations of concepts and theories. He incorporated humor toward the end of the class and he used alternative ways to illustrate important notions. For instance, he walked like a monkey to illustrate the important differences he described between the human and simian skeletons.

The second videotaped class took place after the researcher suggested him to use peer instruction to engage his students more actively, and gave him 300 flashcards. After the investigator explained him in detail how to implement peer instruction using the colored cards, he seemed interested in experimenting with the method. At the beginning of the class, after the flashcards were distributed and he acknowledged the author's presence to the students, he mentioned that he would be using a new instructional method involving the flashcards, and he explained the steps involved. Nevertheless, before proceeding with the class, he added with a skeptical tone: "So we'll see how this works out. All right? I'm an old dog being taught a new trick, so we'll see if anything like this benefits your learning" (Adrian, Video #2).

This second videotaped class had also a fast pace, but compared to the first videotaped class, he used peer instruction with two essential questions. The majority of his instructional methods included conveyance of information, asking rhetorical questions, and questioning students, in the same way he did previously. He continued to move back and forth in front of the students while lecturing, use technology for graphic illustration of notions, and scatter humor throughout. When asked outside the peer instruction questions, students were not allowed sufficient time to answer, and when few of them replied, he did not explore students' reasons for their incorrect answers. However, when using the two peer instruction questions, he followed the instructions carefully. First of all, students engaged in discussions about the possible answers to each question, were allowed longer time to answer, and were allowed to explain their reasoning for two of the possible answers, an incorrect one and the correct one. During students' discussions, he continued to move back and forth in front of the auditorium and observe them from a distance.

The third class showed the same structure: long periods of time used to convey lots of information, use of rhetorical questions scattered throughout, while Adrian was pacing back and forth in front of the students. From time to time, he stopped to question students or ask for their feedback, allowing a very short time for students to answer, and obtaining few questions only from the students who sat in the front. He engaged occasionally in brief discussions with those very few students. This was his style of

teaching: fast pace, lots of information transmitted uni-directionally – from him to the students –, use of rhetorical questions, discussion with a very small number of willing students.

Adrian had the initiative to incorporate peer instruction during the third videotaped course session, after he watched the previous videotape and observed the level of students' active participation compared to the first videotaped session, which he considered it to be of a representative class. The dialogue between Adrian and the researcher, and his reflections triggered by watching the previous videotapes, prompted him to refine the peer instruction technique and observe the effects. Very importantly, he changed the way he requested students' explanation of possible answers, by asking first for the explanation of the incorrect answers, and leaving students' explanations of the correct answer last. This technique increased students' interest in the exploration of alternative answers. Moreover, he allowed more time for students' answers, not only during the peer instruction questions, but throughout the duration of the class. During the two peer instruction exercises, students engaged in ample communicative interactions while exploring all possible answers. Compared to the second videotaped class, Adrian was actively engaged in promoting interaction among students during the active learning exercise: he went up and down the aisles, stopping to answer students' questions, encouraging students to talk with their neighbors, and asking questions intended to clarify students' ideas. In this way, he made the effort to reach the students in the back of the auditorium and basically, to be available to all students in the class.

RTOP scores

The RTOP scores of each videotaped teaching session are included in Table 1. They reflect the descriptions of the teaching methods employed by Adrian, as described previously. Each of the five sections included in the RTOP instrument can be scored from 0 through 20, and hence, each observed class can obtain from 0 to 100 RTOP points (Lawson et al., 2002; Sawada et al., 2000). The total RTOP score represents the extent of student-centered teaching employed by the instructor. High RTOP scores, closer to 100, indicate a student-centered teacher who creates an active learning environment conducive

to student interactions, while low RTOP scores, closer to 0, are indicative of teacher-centered pedagogy. While the RTOP scores did not have a quantitative significance, they intended to illustrate in a more condensed form Adrian's transformation of teaching practices.

Overall, Adrian's RTOP scores increased during the program, mainly due to the incorporation and refinement of peer instruction exercises in his teaching. He managed to improve his lesson design through the creation of a community of learners. His procedural knowledge, which refers to students' scientific reasoning in his class, increased due to students' engagement in making predictions and their active participation in answering challenging questions. While Adrian's scores remained constant for his propositional knowledge, which mainly refers to his knowledge of the subject matter and his ability to connect it to other disciplines or real life, he improved drastically in the domains of communicative interactions and student-teacher relationships. On the whole, the inclusion of peer instruction in the last two videotaped course sessions led to the creation of a more active and socially connected learning environment.

Table 1 - RTOP scores for the three videotaped course sessions taught by Adrian.

	Course session #1	Course session #2	Course session #3
Lesson design and implementation	1	5	7
Propositional knowledge	16	16	16
Procedural knowledge	1	5	6
Communicative interactions	2	8	10
Student-teacher relationships	1	5	7
Total	21	39	46

To summarize, during this program, Adrian implemented peer instruction in his large classes. This was the only student-centered teaching method learned in the

workshop that he was willing to incorporate. Observations of his enactment of this method showed a gradual improvement of his teaching practices and increased active participation of the students. Thus, as a result of participating in the program, Adrian experimented with alternative teaching methods and evaluated the results by watching the videotapes, actions considered to be indicators of engagement in premise reflection on instructional knowledge (Kreber, 2006b).

Summary

Adrian's participation in the program led to minor changes in his teaching approaches. For instance, as a result of his participation in the workshop, he changed his syllabi to convey to students the major course objectives. While he had a positive attitude toward enriching his teaching, he was aware of his resistance to change. His participation in the program increased his engagement in reflection about teaching, from content and process reflections to the higher level of premise reflection. He implemented one active learning method in his large classes, managing to increase students' active participation, but he maintained a skeptical stance regarding the usefulness and applicability of the method in a large-enrollment course. Without additional support, he was unlikely to incorporate student-centered teaching methods in his future large classes.

Case Two – John

Introduction

John was a professor of Chemistry who had been at his current University for approximately fifteen years. He was also the Associate Dean for Teaching and Diversity, and Director of Graduate Studies at his University. He was a male in his mid-forties. John was the leader of a large research group who performed research in the field of Physical Chemistry. His research group included postdoctoral fellows, graduate, and undergraduate students. Hence, he was actively involved in directing student research. He

was a very successful researcher, presenting his findings at international and national conferences in his field, and publishing in peer-reviewed journals. He also was a reviewer for such journals and a recipient of several research grants. Thus, his academic duties were divided among research, teaching, and administrative roles.

John had fifteen years of experience in teaching upper division undergraduate and graduate courses, which mainly consisted of a small number of students. He had no formal teaching training. At the beginning of this study, he had never taught a large-enrollment introductory course, and was preparing to teach a large class for the first time in the spring semester of the academic year 2009-2010.

Conceptions about Teaching Large Classes

John's conceptions about teaching large classes were extracted from his teaching philosophy, his reflection on teaching large classes, and researcher's field notes from meeting with him before the workshop. At that time, having not taught a large class in the past, he could not provide the investigator with detailed information about his pedagogy employed in a large introductory chemistry course. He also could not give her a syllabus until shortly before his large class started in January 2010.

It was evident that John was student-centered and naturally inclined toward incorporating active learning, as exemplified from his statement of teaching philosophy, "I also remember that I was not so long ago a novice learner […] myself, and that the teachers from whom I learned best were those who treated me as a colleague on a journey of discovery. I hope that I am able to bring a similar experience to students in my own classes" (John, Philosophy). John continued to explain how reflecting on his own learning and connecting it with his students' learning, he designed his advanced courses to involve strong interactions between him and the students, and among students. He facilitated class interactions by using guided inquiry to teach his subject, thereby allowing students to design their own experiments in order to answer important questions. He was a firm believer that, to be an effective teacher, he had to make strong connections between the subject matter and real life, and to actively involve students in guided inquiries through experimentation. For instance, he taught his advanced classes in

the laboratory, by alternating lecture with student-led discussion sessions and student-driven laboratory experiments.

John's students were chemistry majors and while he viewed teaching in general, as a way of inducing students' excitement about the subject matter, he also perceived it as a way of building students' skills necessary to succeed in chemistry. For example, in the past, he had taught a one-hour seminar for Honors students at his University. This seminar combined science and non-science majors. He designed this class to promote the formation of a learning community in which students engaged, both online and in person, in discussions about the subject matter. He told the researcher on numerous occasions how he used students' prior knowledge to challenge their misconceptions and make them think more deeply about science in general. John was concerned about the success of his students. In fact, he assessed the knowledge level of the incoming graduate students and based on the results, he offered remedial classes to those willing to attend.

Despite being a successful researcher and having an active administrative role at his University, John perceived himself more as a teacher, than as a scientist. When the researcher first met him, he admitted that teaching acted as a driving force for him to be in the academe. He mentioned that he thought the role of the instructor, even for a large-enrollment course, was that of a facilitator of knowledge. He saw teaching the large introductory course as an opportunity to convey enthusiasm for chemistry and to make it relevant to real life, while providing "a rigorous yet accessible introduction to the world of atoms and molecules to students for whom this might be one of their only (and final) university-level science classes" (John, Reflection).

From the beginning, John thought of teaching a large class by making use of active learning techniques. He did not see it otherwise. While he was excited to design and teach a large-enrollment course, he had several concerns. When reflecting on his future teaching of a large class, he was anxious that this would require an enormous time investment on his part, which could negatively impact his other academic endeavors. When asked about these concerns he said:

> I'm concerned that a large-enrollment […] class that successfully integrates active learning approaches will require an enormous investment

> of time. […] Nonetheless, the reading that I've done to learn about student-centered large-enrollment science classes suggests that the demands on the instructor are considerable. I need to balance the time spent on this class with time spent directing my research group, fulfilling my administrative duties, and serving the greater discipline of chemistry (by reviewing journal submissions, grant proposals, and the like). To put it bluntly, it's quite rare for a faculty member to advance in her or his career based on her or his dedication to 100-level undergraduate education. I want to teach in a way that engages students, and I want to be successful at it – but will this come at a cost to the other aspects of my professional life? (John, Reflection)

John was anxious for other reasons, too. He had never supervised teaching assistants and he was not sure how to handle students who had failed this course in the past. He was unsure of how his dedication and expectations for active learning would impact his interactions with the teaching assistants. Would they know how to do this or even be interested in teaching in this way? John had many concerns and many questions regarding the large class.

At the time when the present study started, John was engaged in the scholarship of teaching and learning. This was evident throughout his teaching philosophy and from the researcher's discussions with him. For instance, he read books and research articles on teaching and learning and was comfortable using the language of teaching and learning. Additionally, in preparation for teaching the large class, he consulted many sources on how to incorporate active learning methods. Hence, he was engaged in content reflection on pedagogical knowledge (Kreber, 2006b). Moreover, in all classes he taught, he experimented with alternative teaching approaches and evaluated the results, thereby engaging in premise reflection on instructional knowledge (Kreber, 2006b). In consequence, before his involvement in the program, John was regarded as an academic engaged in reflection on instructional and pedagogical knowledge.

Participation in the Program

John was one of the initiators of the workshop. Being the Associate Dean for Teaching in his college, he realized the need for the participation of large-enrollment science instructors in a formal teaching training workshop, with the purpose of increasing student engagement. Together with the director of the Teaching and Learning center at his University, he played an instrumental role in persuading these instructors to participate in the workshop. Throughout the two-day workshop, he was very actively involved in all sessions, had many thoughtful interventions, and showed visible enthusiasm.

When the researcher met John at the beginning of the spring semester 2010, he acknowledged his positive impression about the workshop. In fact, from their first encounters, he acknowledged the fact that he was "excited about the possibility to design *de novo* a class that fully incorporates student-centered active learning techniques" and was very determined to teach in a way that engaged students. Thus, his attitude was one of willingness to learn new teaching strategies with the purpose of implementing them in his large class. He agreed to let the researcher videotape his large class four times during the spring 2010 semester, at his convenience. Despite his administrative duties and busy schedule as a scientist who led a research lab and directed graduate and undergraduate students' research, he made every effort to meet with the investigator to discuss his teaching and plan the implementation of new strategies after each videotaped session. To follow the flow of events, Appendix J contains a summary of the outcomes of the engagement in reflective cycles on the transformation of teaching practices.

After the first interview, John told the researcher that he started using clickers (Bruff, 2009) in his class in order to give students attendance points and grade them for correctness of their answers, counting toward their final grade. The investigator used this opportunity to suggest him that he could use these in combination with peer instruction, as discussed in the workshop. He remembered the workshop session on peer instruction and seemed enthusiastic to apply this method in conjunction with clickers. After reminding him the necessary steps to use clickers for peer instruction exercises, he said he would invite the researcher when he decided to apply her suggestions.

The researcher first videotaped John's large class when he used peer instruction for two multiple choice questions in combination with clickers. After sharing his first videotape with him, they met to discuss his teaching approximately one month later. He was surprised when he realized that this new technique was not nearly as time-consuming as he thought it would be initially. Overall, he had a positive impression on how the method influenced students' participation in class, and decided to incorporate it into his teaching more often. While he admitted he was reluctant at first to watch himself in the act of teaching and that he "felt funny" when he started, he considered it a helpful strategy that would improve his teaching. Towards the end, the researcher suggested that he could also use video demonstrations as interactive lecture demonstrations (Shmaefsky, 2004; Sokoloff, Thornton and Laws, 2004). He was reticent to this idea at first. However, after the investigator explained him in detail how he could use the demos to engage students in making predictions, and she offered to e-mail him YouTube videos containing demonstrations of the notions he taught, he was willing to try to incorporate them as interactive demonstrations.

John's large class was videotaped for the second time right before the University's spring break in March 2010. The majority of students were absent and the pacing of the class was slow. He used one multiple choice question as a peer instruction exercise in conjunction with clickers. To illustrate a difficult concept, he invited three students from the audience to come in front of the class, while he asked them to perform certain movements to illustrate the geometry of molecules. While he also used a small three-dimensional model to illustrate molecular geometry, the exercise of having the three students in front of the class seemed to lead to better student understanding. After sharing the second videotape with him, they soon met to discuss his teaching. From the beginning, he was disappointed to see the low level of student engagement and he acknowledged the fact that the timing of the class before spring recess most likely contributed to this result. He asked the researcher if she could suggest ways to make students more involved and ready to participate in discussions with their peers. She suggested that he not show the frequency distribution of answer choices to students after their first round of clicking the correct answer. He was enthusiastic at the idea of not

showing their first round of clicked answers and invited the researcher to videotape him for the third time. He also planned to incorporate clicker questions combined with peer instruction, and also use the YouTube videos that she sent him, as interactive lecture demonstrations.

When the investigator videotaped John's large class for the third time, he used one multiple choice question in combination with clickers and peer instruction. He followed her advice and did not project to the class the frequency distribution of answer choices after the first round of answering. He also incorporated two interactive lecture demonstrations in his teaching, by using YouTube video demonstrations of taught principles. After sharing the third videotape with him, the researcher met John to discuss his teaching two days after the filmed class. He was positively impressed by the increased student participation during the peer instruction exercise. He observed that not showing the first frequency distribution of answer choices to the students, induced students' curiosity and promoted their engagement in discussion with peers, deciding to use this modified strategy in the future. He also had a positive impression about students' participation in the interactive lecture demonstrations. For the fourth videotaped class session, he planned to use Just-in-Time-Teaching (JiTT) questions (Novak, Patterson and Gavrin, 1999) combined with clickers and peer instruction. The use of JiTT questions was presented in the workshop as one active learning strategy to engage students.

The fourth videotaped course session was John's last class before the final exam. He implemented JiTT in conjunction with peer instruction and clickers for two multiple choice questions. Soon after the fourth videotaped course session, the researcher shared the recording with him and they met to discuss about it during the final interview. John's reaction regarding the implementation of JiTT questions in combination with peer instruction and clickers was very enthusiastic. He was very content that students had the opportunity to discuss about the material they read at home before he presented it in class. He also was satisfied that by employing those questions, he identified the overall student confusion and misunderstanding about the assigned readings, which offered him a starting point for teaching the material.

Influence on Teaching Approaches

During the two interviews, John discussed with the researcher about his teaching approaches and his perceptions about the program. John's involvement in designing his large introductory chemistry course was minimal. The department had a committee that established how the subject was taught, in terms of the notions and their corresponding textbook chapters that were presented to students. John was not a member of this committee and he had to follow its guidelines. His syllabus did not include explicit course objectives or learning goals, in spite of discussing this during the workshop. His syllabus included information about the textbook, course outline, grading procedures, homework, his contact details, and the laboratory schedule. However, during class he constantly emphasized the "key skills" that students needed to learn in order to succeed in the course. He also emphasized these basic chemistry skills through the homework exercises he assigned to the students. His focus on skills rather than on the broader learning goals possibly came from his long teaching experience with chemistry undergraduate majors and graduate students, who were at a higher level where they needed to build strong skills, rather than enthusiasm for the subject matter and understanding of the "big picture". During the last interview, he admitted the importance of including the course objectives in the syllabus and stated he would try to do this in his future teaching.

John assumed his students did not possess a solid prior knowledge of chemistry, but that they entered the course knowing almost nothing about chemistry. He tested his assumption by administering a survey during the first day of class, when he asked students about their past experience with chemistry and whether they had taken the same or a similar course before. Based on students' answers, he evaluated their attitudes and overall chemistry knowledge level, which he used later in his teaching of important course concepts. He admitted using students' prior knowledge when he remarked, "I'm using clickers some in this class. And so sometimes I will ask a clicker question, say, "Have you seen this before?", simply "Yes" or "No", so that I can see if people have even seen some of the terminology before, to try to make sure that I am not assuming too much background knowledge" (John, Initial Interview).

John evaluated student learning in various ways. His students had to complete in-class exams, regular homework exercises, and frequent quizzes before coming to class, which were based on the assigned textbook reading material. These quizzes were evaluated either with "correctness points", or with "engagement points", when he did not grade for correct answers, but used them as an indication of student understanding and to explain difficult concepts in class, a form of Just-in-Time-Teaching (JiTT).

Throughout his discussions with the researcher, he stated that he perceived student evaluation as a way to motivate them to read the material and then to practice what they learned, and overall, to integrate important chemistry concepts and demonstrate mastery of the field. John used course assessments as indicators of students' skills and understanding. He was aware of Bloom's taxonomy and its role in connecting learning goals with assessment of learning and hence, he mentioned that he designed his tests to include both recall and synthesis questions. Very importantly, he perceived student assessment as feedback for his teaching effectiveness when he said, "So it's interesting, it's almost, as much assessment of me as of them because it's the only way I really get the feedback from individual students about what material they have mastered" (John, Initial Interview).

As indicated from the two interviews and discussions throughout the program, John's ideas about instructional methods focused on how to incorporate technology into his teaching. John was aware of the general trend to incorporate technology in the classroom, while he was a strong proponent of creating an interactive learning environment in which students interacted among themselves and with the teacher. In his teaching philosophy he included a "self-critique and future plans" section in which he acknowledged his constant avoidance of using PowerPoint and expressed his desire to use it in the future. He believed that teaching with PowerPoint presentations allowed for a higher teaching speed, which would give him the opportunity to present more information to the class. Consequently, John alternated the use of PowerPoint for 10 -15 minutes, with students' engagement in interactive questions. He employed clickers for the first time as teaching aids in the large introductory class. Additionally, John assigned readings for the understanding of simple concepts and devoted class time to explaining

the more complex topics. This differentiation came from his concern that all students need to understand chemistry.

John connected with his students in many ways. He conveyed the importance of his course by showing the students "the beauty of the intellectual world that is chemistry" and by pointing to its connections with other disciplines. For instance, in the survey he administered to students during the first day of class, he asked the students for their college majors. Thus, he knew he had students that were majoring in nutrition, earth sciences, and pre-medicine, and hence, he attempted to make his course relevant by connecting it with the students' fields of interest as indicated by the following statement, "I try to appeal to their sense of what their future profession might be and how chemistry was useful for practitioners of that profession" (John, Final Interview).

John showed contradictory viewpoints about students. During the first interview, he revealed a sense of trust in his students by saying that some of them did not consider the course assignments as chores, but rather they were proud to be able to solve problems and prove to him their understanding of chemistry. On other occasions, he demonstrated having preconceived ideas about his students. For instance, he admitted that students who sat in the back of the auditorium tended to be more disengaged than the other students and hence, had a poor academic performance. Moreover, he observed that many students started with good course participation, but tended to disengage and eventually failed the class, after performing poorly on the first exam. At no time did he attempt to investigate what happened with those students and how he could remediate their situation. Nonetheless, he stated he wanted all students in his class to succeed.

John's conception about student attendance was that by attending class, students had the opportunity to take notes and to understand the material either from him, or from their peers. He did not mandate attendance, but occasionally he used in-class clicker quizzes for which he gave either correctness or engagement points. So, if students were not present, they could not obtain the points, which affected their final grade in the end. He believed that coming to class was important because of the social interaction involved, considering his class promoted strong student interaction and collaborative problem solving. He remarked about class attendance that, "Coming to class is important

because if you don't come to class you'll miss out on the small group interactions, which is where you bounce ideas off of your colleagues and you maybe can ask them how to solve a problem if you're embarrassed or you don't want to ask me how to solve the problem" (John, Initial Interview).

When the researcher asked John how he facilitated interactions between him and the students in his large-enrollment course, he stated that by constantly questioning his students about the material, engaging in discussions with them during and after class, and regularly asking for feedback, he managed to maintain close contact with his students. For instance, his class was allotted 75 minutes, but he conducted it in 50 minutes and then he made himself available to students' questions for an additional 10-15 minutes. Furthermore, pertaining to students' in class interactions with one another, while he did not provoke debates in his large class, he facilitated collaborative problem solving and promoted active class participation in other ways, such as this description:

> I do give students partially completed examples or problems that the first step has been worked explicitly and then the second step has been left blank. But I haven't done that with the intention of provoking debate. Instead that's often one of these instances where I'll ask the students to work together in a group and then to come up with an answer that they use the clickers to register. So there could be a debate in that group that I don't know about, but I haven't designed the problem to provoke a debate and I don't know if a debate is going on or not (John, Initial Interview).

During the first interview, John identified several constraints to facilitating class interactions, such as the large number of students, insufficient class time, and classroom seating scheme. For instance, due to the large auditorium-style classroom, he complained that he did not have eye contact with all students and could not see their facial expressions to use them as clues for students' understanding. Nevertheless, during the last interview, after implementing several active learning methods and observing intense student interactions, he perceived the classroom seating scheme as the only constraint. It seemed that by using these student-centered teaching methods, he became confident that

promoting student interactions in a large class was not time consuming, but feasible and effective.

It was important for John, as an instructor, to build students' chemistry skills. And by skills, he referred to problem solving abilities and ways of thinking that became habitual and indicative of mastering the subject matter. He judged his overall teaching effectiveness based on students' academic success. In class, he evaluated his success as an instructor based on students' reactions and participation. For example, he described:

> I was very pleased that by the middle of the class students would start to ask questions in this large lecture, and I was afraid that there wouldn't be very many questions and having the questions was very important to me to help me either confirm that I was kind of moving the class in the right direction, or to understand possible sources of confusion. And without those interchanges I would have felt less sure of myself (John, Final Interview).

To achieve teaching effectiveness, even from the first interview, he mentioned that he was using quizzes based on reading assignments, and that he relied heavily on visuals to reinforce or illustrate important concepts. For example, he included Marie Curie's picture in the corner of slides that contained important equations, diagrams or notions, which he considered important for conceptual understanding. These strategies were presented and discussed during the workshop. Also, he demonstrated the relevance of his course by focusing on the big picture and connecting course notions to real life and his students' interests. During the last interview, John admitted that, "So, what was successful for me was not to just absorb the material from lecture, but to become more actively engaged with it" (John, Final Interview). John believed that teaching was a dialogue between students and him about learning, as evidenced by the following quote:

> When I started, I thought that teaching meant that we had a book and a syllabus and a lot of material, and we have to make sure that we learned as much material as we could. But now I think I see teaching more as a way to open a dialogue between the instructor and the student about what the subject matter means, how it relates to other areas of learning, how it

> relates to things in the so-called "real world," especially for my class, which is focused on many abstract concepts and dealing with microscopic things like atoms and molecules, and also a way to try to build a foundation for students to become more independent learners and independent thinkers (John, Final Interview).

John identified his role as instructor of a large introductory course with one of a facilitator of knowledge who helped students understand the material while actively engaging with it. Moreover, he admitted he perceived himself more as a teacher than a scientist, when he offered this formula: "two thirds teacher and one third scientist".

Even from the beginning of the spring semester 2010, when he had been teaching the large course for just a couple of weeks, John admitted that he considered it to be a "rewarding" experience. Nevertheless, he acknowledged multiple negative aspects of teaching such a large class: his lack of autonomy for course design, the large population of mixed students with various chemistry backgrounds, insufficient class time, the physical setting conducive to less contact with students than in a small class, and the lack of timely connections between the material studied in lecture and that studied in laboratory sessions. He continued to recognize these teaching constraints until the end of the study.

Despite these impressions about teaching a large-enrollment course, his attitude toward the incorporation of various student-centered, active learning methods was positive and evolved throughout the study. For instance, during the first interview, John demonstrated his willingness to learn new strategies by enthusiastically asking the researcher for ideas. Throughout the program and during the reflective discussions about the videotaped lessons, he constantly asked for her ideas and support in implementing new teaching methods. He did incorporate many active learning techniques in his teaching. Nonetheless, in the last interview, he revealed a personal dilemma that surfaced only at the end of the study, when he remarked:

> And what I still fight against is the idea that all of these other types of activities take "time away" from repetition of what's in the textbook, or working another problem on the transparency, or showing more slides of

> PowerPoint. I have to become more comfortable with the fact that on these other occasions there's learning going on, which is a different kind of learning, and can maybe be more effective learning than simply advancing to the next slide and showing… So, that's the eternal struggle that I'm facing (John, Final Interview).

At the end of the program, when asked about his impressions of implementing active learning methods in his large class, he first took into consideration students' evaluations, which indicated an overall positive reaction to the use of clickers and interactive questions in class. Also, throughout the program, he was surprised to realize that using different active learning methods was not time consuming. In the end, he believed that the use of reading quizzes that students had to complete before coming to class was not a way to engage students with the material, but rather to get used to it before discussing it in detail in class.

Throughout the duration of the program, the investigator examined and explored John's attitude toward participation in the program. She felt that he had become more student-centered as a result of the participating in the workshop. For example, he administered a learning style questionnaire during the first day of class, to evaluate the diversity of students' approaches to learning. He used a survey to determine students' majors and their personal experience with chemistry, for the purpose of targeting examples he used during the course. These were ideas contained in the workshop which evidently influenced John's teaching. Watching himself in the act of teaching prompted John's attention to the different levels of student participation triggered by various teaching methods. When the class seemed more static, he questioned why this had happened, and then he reacted by implementing new active learning methods. John analyzed how he implemented certain teaching methods and accordingly, he had pertinent ideas about the improvement of those methods. For instance, he realized that he spent a very long time switching the computer between his PowerPoint slides and the clicker questions. After watching the videotapes and reflecting on his teaching, he had a very good suggestion about eliminating this time consuming process by having the

clicker questions set up on one laptop, and the slides on another laptop. When explaining what happened, he said:

> I guess what I was always worried about was one of the goals, is to try to engage the students with the material, with me, with each other. And if the clickers take too much time to be setup, then that engagement all dissipates. So, figuring out either a way to minimize the amount of time required to setup a clicker question or to use it more constructively to promote engagement, instead of for students to start talking about what they did over the weekend, or reading the newspaper, or whatever (John, Final Interview).

He also looked at his mannerisms. For example, after watching his first videotape, he noticed that while writing on the Smart Board, or setting up the computer either to project slides or clicker questions, he did not make eye contact with the students, which he thought impeded his ability to connect with them. In consequence, toward the end of the study, he reduced as much as possible the time spent looking at the computer screen. He noticed that while he lectured, he paced in the front of the auditorium and he believed that his constant movement was distracting to students. Admitting he "felt funny" at first, after he surpassed his reluctance to watch himself, John felt that watching his teaching videotapes was very helpful. He admitted that watching the videotapes during this program would influence his future teaching. About the video viewing, he said:

> The videotape where the three students came to the front of the room, I thought that that was very successful for both communicating an idea, but also promoting student engagement. And that's not something I would have tried to find opportunities for, but now I want to find opportunities for getting some students out of their seats to illustrate some kind of topic or principle or concept. Because I think it provides a different way of communicating the idea, but it also brings the whole class together as one body engaged with the material. (John, Final Interview)

In the last interview, John declared that discussing with the researcher about his teaching throughout the program, participating in reflective dialogues about his teaching

practices, as observed from videotapes, and asking for her advice when he did not know how to improve a teaching technique, had a great influence on his teaching practices and on students' engagement in his class. For instance, after the investigator recommended he did not show the frequency distribution of the first answer choices for the peer instruction clicker questions, when students felt disoriented that the distribution of first answers was not shown, he told them that this was a faculty developer's suggestion. Throughout the program, John followed the researcher's recommendations and asked for her advice regarding effective ways to incorporate active learning methods. About this assistance, he said:

> First of all, the discussion about blanking the first responses of the clickers to help promote more engagement in discussion, and then the suggestions that you had about using YouTube, instead of a true demonstration, to have a virtual demonstration. Those both came directly out of our conversations. And both were very helpful techniques. […] So, that's something that I would not have thought of on my own and I appreciate that you suggested that (John, Final Interview).

John's participation in the program had a great influence on his teaching beliefs and behaviors. John was naturally inclined toward student-centered teaching and gave thought to how students learned most efficiently in his classes. He was engaged in the scholarship of teaching and learning by constantly reflecting on student learning, reading books and research articles about the teaching and learning of chemistry, and being involved, at an administrative level, in teaching in his College. Thus, from the beginning of the present study, John was an academic engaged in content reflection on pedagogical knowledge, and by experimenting with alternative teaching approaches, he was involved in premise reflection on instructional knowledge (Kreber, 2006b). Nevertheless, learning new teaching methods, applying them in his large class, then reflecting on his teaching and discussing it with the researcher, gave him a different perspective. By describing the instructional strategies he used, collecting information about students' perceptions of his methods, continuing to experiment with alternative teaching approaches and analyzing the results, comparing different instructional strategies for their applicability in a different

context, paying attention to the end of term teaching evaluations, and administering learning styles and other inventories to students, he engaged in content, process, and premise reflection on instructional knowledge (Kreber, 2006b). Moreover, by gathering feed-back from students on their learning of discipline-specific concepts, such as with his first class survey, he engaged in process reflection on pedagogical knowledge (Kreber, 2006b).

John had valuable ideas for future faculty enrichment programs that targeted promotion of student engagement for instructors of large classes. He suggested that learning from peers could lead to an increased perception of the implementation of active learning methods as feasible and efficient when used in the large class. For example, he mentioned that showing videotapes of colleague professors while they used these methods would make the approach more concrete and would reduce the factor of being uncertain or fearful about their implementation. Very importantly, he acknowledged the important role of engagement in reflection and dialogue about teaching. He thought of this as a mentoring opportunity for young faculty when he said:

> Well, I enjoyed the discussions that you and I had after you videotaped my classes. And I think that, in many cases, faculty would benefit from having somebody visit their class and just observe and then discuss it with them afterwards. Like just to promote more self-reflection about, "Why did you do that, did you think it worked, what might you do differently". A lot of that is very caught up in evaluation of teaching as a part of tenure and promotion, which can be very, it can make assistant professors, in particular, very tense and insecure, but if we could find some way to do it as a kind of professional development activity instead of an assessment activity, then I think that faculty could benefit (John, Final Interview).

Influence on Teaching Practices

John was videotaped four times during the program and his teaching practices were analyzed and then evaluated by using the RTOP. Appendix J contains a summary of

the outcomes of his engagement in reflective cycles on the transformation of teaching practices.

The researcher first videotaped John's large class while he used two multiple choice questions as peer instruction exercises in combination with clickers, following the researcher's suggestion. He projected the question, explained it, and then he let students work on the question before clicking their first answers. He then projected on the screen the frequency distribution for each answer choice. After this, he encouraged students to engage in discussions with people who gave a different answer, to try to persuade each other of the validity of their answers. He then asked students to click their answer choice for the second time and projected on the screen the frequency distribution. In the end, without asking for students' explanations, he explained the correct answer. During his lecture, he stopped constantly to ask for students' feedback and whenever he had questions for students, he allowed sufficient time for students' answers. Because he waited a long time after each question or request for feedback, students were encouraged to answer his questions and ask their questions when they needed. For example, few times during this class, he engaged in discussion with students based on their questions to him. He used technology for illustration of certain concepts and overall, he seemed to rely on technology and be physically engaged with the computer set up in a way that minimized his contact with the class.

The second videotaped class took place right before the spring 2010 recess, when the number of the students in the class was smaller than usual. The course was very slow paced and he made use of one clicker question as peer instruction exercise. Students' participation in peer instruction was reduced compared with the first videotape. John relied on technology to offer visual aids for important concepts, but he also used alternative ways of illustration. For instance, to explain how intermolecular forces influenced the geometry of molecules, he invited three students from the audience in front of the classroom. He asked them to simulate certain forces by letting them gently pull the arms of one another, to model the forces among atoms in a molecule. Thus, they exemplified how these forces affected the spatiality of a molecule. John conveyed course information in a lecture format, but he stopped regularly to ask for students' feedback,

question students, or engage in discussion with them. He allowed sufficient time for students' answers and questions.

The third videotaped class had the same slow pace, which allowed students to answer John's questions and made them comfortable to ask questions when they needed. He used one multiple choice question as peer instruction in combination with clickers. Based on the low student participation in peer instruction during the previously videotaped class, and after discussing about this issue with the researcher, he did not show the frequency distribution of the first clicked answers. This prompted a reaction from the students, who asked him to project the distribution of the first set of clicked answers. After this event, students interacted more intensely one with another, and engaged in ample discussions about the validity of their first answers. After students clicked their second round of correct answers, John explained the correct choice. During this class, John also used two videos as interactive demonstrations for the illustration and understanding of important concepts. He played the videos, stopped them before an important part to ask students for predictions, then continued to play them. Thus, while students had the opportunity to understand abstract concepts by connecting them with real life phenomena, they were also actively engaged in the process of understanding.

In the last videotaped class, John engaged students in two peer instruction clicker questions, which were questions from the material that students had to read at home, and hence were considered JiTT. While for the most part, John conveyed important information in a lecture format and made use of several rhetorical questions, the students actively participated in class during the peer instruction exercises. The class had the same slow pace, with long periods of time allowed for students' answers. He stopped regularly to ask for students' feedback and made use of real life analogies to illustrate abstract concepts. Overall, students interacted with him and among them, but when they engaged in discussion with him, John did not explore their alternative answers, but preferred to explain the correct approach himself and then move on.

RTOP scores

The RTOP scores of each videotaped teaching session are included in Table 2. They reflect the descriptions of the teaching methods employed by John, as presented previously. While the RTOP scores do not have a quantitative significance, they do illustrate well John's transformation of teaching practices.

Overall, John's RTOP scores increased during the program, due to the incorporation of several active learning techniques: peer instruction, JiTT, interactive lecture demonstrations, and use of clickers. While the levels of student-teacher interactions were maintained fairly constant from the beginning to the end of the study, he improved gradually with regard to the other RTOP sections. In the final stages of the study, John's propositional knowledge attained the maximum RTOP points, showing his increased ability to solicit students' ideas and their active participation in a learning community.

Table 2 - RTOP scores for the three videotaped course sessions taught by John.

	Course session #1	Course session #2	Course session #3	Course session #4
Lesson design and implementation	9	8	14	13
Propositional knowledge	15	16	20	20
Procedural knowledge	7	5	11	9
Communicative interactions	14	14	17	17
Student-teacher relationships	11	10	13	12
Total	56	53	75	71

To summarize, throughout the program, John increasingly made use of active learning methods in his large class. He showed that he reflected upon student learning and had a positive stance toward his collaboration with the researcher. He made use of

clickers for the majority of questions he used in class. Additionally, he used clickers for peer instruction and JiTT exercises, and employed interactive lecture demonstrations. Following his participation in dialogue and reflection on teaching and student learning, and researcher's observations of his enactment of active learning methods, John demonstrated his inclination toward student-centered teaching.

Summary

John perceived himself more as a teacher than as a scientist. At the time when this study started, John had never taught a large-enrollment class. Nevertheless, he was naturally inclined toward student-centered teaching as a result of his overall teaching philosophy. He engaged in content reflection on pedagogical knowledge by reading books and research articles on teaching and learning, and consulting different sources on how to incorporate new teaching methods in his classes. Moreover, he had been experimenting in the past with new teaching methods and evaluated their results, thereby engaging in premise reflection on instructional knowledge. His main focus as a teacher was on building students' skills necessary for mastering chemistry.

John's participation in the program led him to a gradual increase of incorporation of active learning methods in his teaching. He enthusiastically engaged in reflection and dialogue about his teaching behaviors. As a result, he adopted many teaching strategies learned in the workshop.. He was likely to continue to collaborate with the Teaching and Learning Center at his University and to implement new student-centered teaching in his large class.

Case Three - Siobhan

Introduction

Siobhan was an assistant professor of Physics, on the tenure track since her University appointment in 2006. Siobhan was a British female in her mid-thirties. She

was a group leader, directing postdoctoral, undergraduate and graduate student research in the field of Nuclear Astrophysics. She was a very successful researcher, being a recipient of research grants and publishing intensively in peer reviewed journals. For instance, in the summer of 2009, she received the prestigious Outstanding Junior Investigator Award from the U.S. Department of Energy. The award recognized Siobhan as an exceptional scientist early in her career by supporting the development of her individual research program. In the same year, she was also the recipient of a junior faculty research/creative achievement from her University. Very importantly, at the end of her participation in this study, in the spring of 2010, she published a seminal paper in *Nature*, a very prestigious peer-reviewed scientific journal. Additionally, at about the same time she was the recipient of a faculty advising award from her University. She was also a major publication reviewer, a National Science Foundation grant reviewer, and participated actively in the organization of the Science Olympiad and the Day of Science at her University. Thus, her academic duties involved participation in research, university service (e.g., sitting in different academic committees), and teaching. Among her undergraduate teaching, every spring semester she taught a large-enrollment second-year Physics course for students majoring in engineering.

Siobhan had an interest in teaching. Concurrently with the American Physical Society, she attended annually the conference of the American Association of Physics Teachers (AAPT) where she also participated in workshops on the teaching of Physics. This is where she learned about Just-in-Time-Teaching (Novak, Patterson and Gavrin, 1999), which she started to implement in her undergraduate small enrollment class in the fall semester of 2008. She personally met Professor Eric Mazur, from Harvard University, when he visited her department in the fall semester of 2008. At that time, Dr. Mazur gave a presentation on how to implement peer instruction in the teaching of large Physics classes (Mazur, 1997). Siobhan was very enthusiastic about applying his ideas in her classes and thus, she started employing this active learning method in all her undergraduate classes, including the large-enrollment course. Moreover, at the end of the study in May 2010, a paper authored by her got accepted for publication in *The Physics Teacher*. The paper described the current landscape of research in Nuclear Physics and

the available resources for the teaching of Nuclear Physics in middle and high school. At about the same time, she received a creative teaching grant from the Center of Teaching and Learning at her University, to be used during the academic year 2010-2011.

At the beginning of the study, Siobhan had been teaching for two years, from which her experience in teaching a large-enrollment class spanned two semesters. She had no formal teaching training. At the beginning of this study, she followed her Dean's advice to attend the workshop, with the purpose of enriching her teaching of the large class.

Conceptions about Teaching Large Classes

Siobhan's conceptions about teaching a large-enrollment class were extracted from various sources. For instance, her syllabus for the large-enrollment course was very detailed. She included information pertaining to course communication and course philosophy, additional to the information regarding the course outline, assessment and grading. This course document was very informative about what students learned and how.

At the beginning of the study, Siobhan had been using peer instruction and JiTT in her classes. Her experience of using JiTT was a negative one – "I killed myself with JiTT" -, having tried it for one semester with her small-enrollment undergraduate class. Her impression of using JiTT was that it was very time consuming and the effects on student learning were not significant. She was not willing to implement it again in her classes. On the other hand, she had been also using peer instruction in both her small- and large-enrollment classes and was very enthusiastic about its effects on student learning and active class participation. After attending Mazur's workshop on how to use peer instruction, she read his book on the method, thereby engaging in content reflection on pedagogical knowledge (Kreber, 2006b). As a result, at the beginning of the study, Siobhan was using peer instruction routinely in her classes. She did not use clickers, but she developed colored flashcards which students used to show their answers. By judging from the color of the flashcards, she was able to visually evaluate her students' responses. From time to time, she also combined peer instruction with lecture demonstrations. She

explained her strategies by saying, "I try where possible to link peer instruction to demonstrations, so the students try to work out the outcome before I perform the demo. This method has the most rewarding outcomes, as it stresses the connection between what we teach in class and the real world, i.e., encouraging more expert beliefs" (Siobhan, Philosophy). Another motivation for using this method was that students reacted well to it, thereby showing that she took into consideration students' reactions in class and their comments at the end of the course. Hence, she engaged in process reflection on instructional knowledge (Kreber, 2006b).

Additionally, she used online forums to promote students' discussion about course-related topics, which she constantly monitored and made part of the students' final grade in the course. By experimenting with alternative teaching approaches and checking out results, Siobhan was engaged in premise reflection on instructional knowledge (Kreber, 2006b). Moreover, at the beginning of her large course, she administered the force concept inventory (Hestenes, 1992), an instrument designed to assess students' understanding of the most basic concepts in Newtonian Physics. Thus, she also engaged in process reflection on pedagogical knowledge (Kreber, 2006b). She was always willing to describe her use of peer instruction, thereby being involved in content reflection on instructional knowledge (Kreber, 2006b).

Siobhan did not like teaching a large-enrollment class. She felt that the physical setting, the limited time, and the large number of students, represented considerable impediments in establishing relationships with the students. For instance, given her interest in student learning, she was concerned she did not spend enough time with each student which she expressed by remarking, "[the problem] is that you can't have much one-on-one contact time. And I feel that, and I find that hard, that I can't really spend a lot of time with each individual student, get to know them, understand where they're having problems, that kind of thing" (Siobhan, Final Interview).

Regarding her teaching of a large-enrollment course, her impression was that having only two hours per week represented very limited instructional time. She considered that students would benefit from having an additional hour dedicated to problem solving and additional active learning, such as interactive demonstrations. To

this end, she pointed to the difficulty of setting up lecture demonstrations because the department did not have a person designated to organize and take care of the demonstration equipment. She felt that the lecture was disconnected from the laboratory activities, which were in fact considered a part of the course. While she recognized that the organization of the laboratory was not included in her duties, she complained about this disconnect, mostly because the students in her class were engineering majors who would benefit immensely from connecting the abstract concepts with their practical applications. In the end, Siobhan admitted that her department, aside from sharing lecture notes, was not involved in mentoring of junior faculty, like she still was. She seemed regretful and wished that she could have a teaching mentor.

Judging from her teaching methods, Siobhan was a student-centered teacher. Active student participation was a constant component of her teaching. She had an encouraging, positive attitude toward her students, whom she saw as partners, which she expressed by saying, "As much as possible I try to make the student an active partner in learning. This means that I can't just use passive lecturing techniques" (Siobhan, Philosophy). Sometimes, however, she showed her disappointment in students whom she said were, "motivated solely by the grade they can achieve, and that can become almost demoralizing for the teacher" (Siobhan, Reflection).

Siobhan perceived herself as a scientist-teacher. But above all, she considered herself a learner. She did not put herself in the center of her students' learning, but instead believed that she just led the students in the right direction. She was deeply engaged in the scholarship of teaching and learning. As explained above, at the time when the present study started, Siobhan was already engaged in content and process reflections on pedagogical knowledge, and in content, process and premise reflections on instructional knowledge.

Participation in the Program

Siobhan's participation in the workshop was very active and enthusiastic. During sessions dedicated to discussing about JiTT and peer instruction, she recognized her use of both methods, described the methods, and shared with all workshop participants her

opinion about using each of them. She also showed her interest in other active learning methods, by asking questions to workshop mediators and colleagues who have been experimenting with them. Soon after the workshop, she contacted the researcher to invite her to visit her classes.

During the fall semester of 2009, the researcher conducted the first interview with Siobhan and visited her small-enrollment class. She asked the investigator's opinion about her teaching approaches in that class and was very open to her suggestions. They met again during the spring semester of 2010, when Siobhan was videotaped four times while she was teaching the large-enrollment class. From the beginning, she told the researcher that she changed the syllabus slightly by including a section on class environment. This was one aspect of course organization that was discussed in the workshop. The classroom environment section in her syllabus informed the students that the course atmosphere was intended to be comfortable and open, allowing both students and teacher to discuss the material. She mentioned that she included this section as a result of the workshop discussions, being convinced that it would prepare the students for her communication-based course. She added that she included in the large class some of researcher's minor suggestions from the previous semester, such as when working the homework exercises with the students in class, she allowed the students to work out the problems before she gave the explanation. She was very confident in her abilities to incorporate active learning in her teaching and hence, she volunteered to offer the videotapes of her lessons that would follow to the Teaching and Learning Center, to be used as material in faculty development activities.

To follow the flow of events, Appendix J contains a summary of the outcomes of Siobhan's engagement in reflective cycles on the transformation of her teaching practices. Siobhan was videotaped for the first time when she invited the researcher to see how she taught using peer instruction. She used five multiple choice questions with colored flashcards to monitor students' answers. Apart from when she used this active learning technique, she lectured while making use of a few PowerPoint slides. After obtaining the videotape, the researcher met Siobhan to discuss her teaching approximately one month later. Siobhan's first comments pertained to her mannerisms

and how she looked or talked. Eventually, she expressed that the peer instruction questions took too much time because she allowed students a long time to answer. To expose students to a variety of learning approaches, and because the lecture material tended to become very abstract, the researcher suggested the incorporation of interactive demonstrations in Siobhan's classes. And instead of performing the demonstrations herself, the investigator proposed she used YouTube videos. She seemed to be aware of few videotaped demonstrations available on the internet, but did not commit to including them in her teaching at any future time.

Siobhan invited the researcher to videotape her second large class when she again made use of peer instruction. This time, the pace of the class was faster than before. She wanted the researcher to videotape the class from the front, so it would be visible how the majority of colored flashcards shown by students changed after they engaged in discussions with their peers about the question. She used four multiple choice questions as peer instruction, when students applied concepts that she taught in class. Her lecture preceded the peer instruction exercises. After watching the videotape, they met to discuss about it. This time, she seemed to be in a hurry, admitting that she watched the videotape just before she met with the researcher that same day. She did not have any comments about her teaching. At this time, the author shared with her several video demonstrations related to the topics discussed in her class. She informed the researcher that she planned to use interactive lecture demonstrations during the last class, when she invited her to attend and videotape it.

Siobhan was videotaped for the third time when she used peer instruction with only one question. The lecture was short and fast paced. Aside from using peer instruction once, she lectured and spent the majority of the instructional time explaining mathematical equations. At the end of the lecture, she told the researcher that she would not have time to meet with her or watch the videotape due to her extremely busy schedule. She invited the investigator to videotape the last lecture, when she planned to include interactive lecture demonstrations.

The fourth videotaped class was Siobhan's last class of the semester. For the majority of the instructional time, she performed demonstrations to illustrate important

concepts in the course. She asked for students' predictions before performing the demonstrations herself, a strategy discussed in the workshop and then suggested during by the researcher during their conversations. The majority of students participated in these interactive demonstrations. She invited few students to the front of the class to help with the demonstration, too. She used the two videos provided by the researcher, containing demonstrations of course concepts. She stopped the videos and asked for students' predictions before she continued to show them to the end. This was a strategy previously suggested by the researcher in reference to the interactive demonstrations. After obtaining the last two videotapes, Siobhan met with the researcher to discuss about them during the last interview. Siobhan' comments after watching these last two videotapes indicated her astonishment after comparing them to the students' final evaluations of the course. Apart from showing overall content with her practices, when asked specific questions about her teaching, her remarks were without substance.

Influence on Teaching Approaches

During the two interviews, Siobhan and the researcher discussed her teaching approaches and her perceptions about the program. Her involvement in the organization of the course was minimal. First of all, because many instructors taught the same course, the department as a whole chose the textbook and the chapters to be taught from it. Secondly, when she first taught the course, she received all the teaching materials (i.e., course notes, PowerPoint slides, homework exercises, and tests) from the professor who taught the class before her. While she admitted that the first time she taught the large class she used her predecessor's teaching materials, she added that after she met Professor Mazur and learned about peer instruction, she had a major switch in her teaching methods. Consequently, teaching with this active learning method changed her involvement as an instructor of a large class. She embraced the student-centered teaching style and incorporated it more often. She created her own conceptual questions. Overall, she renounced her initial teaching approaches and embraced this more interactive student-centered approach.

Siobhan organized her large course around important concepts in electricity and magnetism, which was the topic of the class. Even though she did not include a section dedicated to course objectives or learning goals in her syllabus, in general she focused on students' understanding of relevant concepts. She was not interested in her students' "mathematics skills", but rather in their understanding of important physics concepts. She said:

> So you have to decide firstly what is important, what you have some personal attachment to in that material. And I know I have a strong bias in this, I really do. I have a strong bias towards concepts and at your understanding of the world. Even if your mathematics is sometimes a little bit hand-wavy, I would rather you came out really understanding this is why that happens. But that's what I'm looking for. So, when I look at the material that I'm teaching, I try, you know, doing this trying to think, "What is the essence of this? What is really important? What do I want them to walk out of the room knowing and understanding?" And that's the most important thing, to doing that is to knowing your own level of what it is you're trying to get across. It's very easy to do that through a lecture and just go through the material piece by piece by piece. But to try and have something in your head that's stringing it all together and say, "This is what's important". Otherwise you can't communicate it to the student (Siobhan, Initial Interview).

Siobhan did not assume that her students had more than basic knowledge of the material she was teaching. She mentioned that she assumed her students knew the material included in the pre-requisite courses, and for specific information, she talked with her colleagues who taught those courses.

Regarding the aspects related to course assessment and student evaluation, Siobhan admitted that she set clear expectations for the students from the beginning of the course. In the syllabus, she stated that she did not intend to curve the results of students' tests. Her opinion about curving grades at the end of the course was that it did

not provide the students with clear expectations nor did it motivate students to stay in the course. She explained further when she said:

> If you curve at the end, thinking "Oh, what am I going to do, I'm getting a D all the way through and all of a sudden I get a B". Do you see what I mean? You make them feel bad all the way along, then suddenly "Oh, now you're doing all right." "All my students were averaging around a D, so I had to curve you all up to B." I don't like to do that. I like everything to be known. That's why I have such a long syllabus as well. This is my contract with you. I'm telling you if you get this percentage, you'll get that grade. That's how it is and I don't curve (Siobhan, Final Interview).

The tests that she created included three parts: factual, numerical, and conceptual, which she said reflected similar aspects of the course. These were used to integrate important course notions. By applying her personal experience as a learner of physics, she said that the course exams should be "not just an assessment tool, but actually a learning tool". For example, she mentioned that at one point, she gave an exam which contained an application problem that required students to apply what they learned in a context that they had not encountered before. Siobhan said that students did not know how to approach that problem and that they complained about it to her. Moreover, she considered that students' exams could be used as feedback for the teacher when she said, "I like to ask them questions on an exam that we have actually discussed, exactly that question. You know, not everything I put in exam we've done exactly in class, but one or two things just to see, it's so I get some feedback how that discussion went. At the time I think the discussion went one way, but then when you have to test them on it" (Siobhan, Initial Interview). Overall, Siobhan was interested in students' conceptual understanding, and considered that assessment tools were indicators of such understanding and hence, of learning. She mentioned that, provided the students put effort into participating in class, did the homework problems, and attended the laboratories, they should succeed in her course.

Siobhan enjoyed discussing her teaching approaches, by describing her teaching methods and reflecting on her rationales for each of them, which served as indicator of

her engagement in content reflection on instructional knowledge (Kreber, 2006b). She used various teaching methods in her large class, such as lecture, peer instruction, and occasional demonstrations, combined with students' involvement in out-of-class online forums. Thus, she constantly embedded students' active participation both in class and outside of class, into the course. She made use of technology through her minimal employment of PowerPoint presentations, and by using the Blackboard course interface, where she posted her course notes, slides, solved homework problems, and encouraged students to use the Discussion Board for any questions related to the course.

When she designed her lessons, she first thought about how they would benefit her students. For instance, the students in her large class were engineering majors and hence, despite her theoretical approach to the subject, she always included applications in her lessons. She said that,"…engineers particularly like to see applications, so sometimes it's more, well, you can, you know, talk about applications, they like that. I don't know if I'm so good at that. Because I don't think it's always about application and I want all engineers to see that sometimes it's just, for the sheer joy of understanding" (Siobhan, Initial Interview). Siobhan's main teaching goals were to promote students' conceptual understanding and "to instill in students some faith in science". While she combined the teaching of important physics concepts with their applications, she also put those concepts in a historical perspective. She remarked, "I'm trying to change the way of thinking and viewing the world. I care about what it is they learn, much more than what grade they go."

Siobhan did not mandate attendance and emphasized that it was one way for students to participate in class and hence, have the opportunity to understand and learn the concepts. She offered the following explanation:

> I don't take attendance. I think the student needs to learn the material. The student has to learn the material. They do that whichever way they can. […] So my role is, yes, a resource for their learning. And I try and really put, it is on them, right? That they're adults, this is not middle school. We can't force them to come to every class. I think I have a different idea to the university on this. The university is very into attendance in this state. If

> they give them the student money, they want to see that they're attending the class. And I want to see that they're participating in the class, it's something different. […] If you've got students who are not coming to class and acing everything, that's fine by me. But if you've got students who are failing and not coming to class, well, I don't have a lot of time for them (Siobhan, Initial Interview).

So, Siobhan placed the responsibility for academic success entirely on the students. She said that many of the students did not learn because they did not want to be there. Some of the reasons she gave for this were:

> The people I have in my class are people who know that they need to get a university degree if they're going to get any kind of decent job. And some of them are really interested in engineering, and some of them have been told by their parents or other people that engineering is a good way to go, and they don't necessarily have much interest in what it is I'm trying to teach them about. And when there's a lot of them, you know, it's very easy for them to disconnect, even if they're sitting there in the classroom and I'm standing at the front doing whatever, they can just turn off because they don't want to be there, you know (Siobhan, Final Interview).

Overall, Siobhan made every effort to actively engage the students with the material in- and out-of-class and was concerned about their conceptual understanding. Through her constant use of peer instruction, she promoted active student participation which she considered extremely important in the process of learning. By asking conceptual questions, she facilitated students' engagement in discussions with her, and outside peer instruction, with their peers. For example, she initiated and encouraged students to participate in debates, mostly in the online forums. She stimulated students to participate regularly in online discussions as part of the course, by giving extra credit to those students who did this constantly throughout the duration of the course. Finally, she considered that the interactions with students and among students were her "strengths". Siobhan believed that she had made great progress from her first teaching experience when she said:

> I think I've made great steps in this from the first time I taught it. And the first time I taught it, I really did teach it straight from the PowerPoint. I mean, you know, I didn't know what I was doing, and I stood there in front of the class. I was like "What do I say now?" I actually printed out the PowerPoint on separate sheets and you know… I'd been used to talking to other physicists for so long and not talking to students. And moving from there to this Peer Instruction model, and really asking questions of the students, and getting them to speak to me as well as use the flashcards. I feel that, you know, that it's a lot better than it was. Also, through the discussion board, I do see that there are discussions going backwards and forwards between the students there (Siobhan, Final Interview).

She considered that she inherently facilitated class interactions by showing her openness to her students, but mainly by constantly engaging them in the peer instruction exercises. Siobhan regarded her exchange of information with the students during the peer instruction exercises, as a way of establishing good pathways of communication. Students were used to communicating with her in class and hence, this atmosphere facilitated the creation of two-way communication patterns maintained throughout the course. Pertaining to the interactions between teacher and students and among students in her large class, she considered that the workshop provided her with a good tool to communicate to the students about the course relationships. For instance, as a result of her participation in the workshop, she included in the syllabus a new section titled "class environment", where she included information about the open course atmosphere, encouraging students to ask questions and participate in class discussions.

Another very important teaching goal for Siobhan was to build students' team-work skills. Consequently, she motivated her use of peer instruction, not only in terms of how it benefited students' conceptual understanding, but also how she used it as an exercise necessary to build students' skills for working in teams later in their careers. She considered that since engineers worked in teams, she had to build her students' skills for being able to become active, productive members of those professional teams. About teams she said:

> Well, I come back to the discussion board and also the peer instruction. I think that uses student-student interaction. I think that is important. […] Again, because I think engineers work together in groups. And not just with other electrical engineers. It's quite often you're going to have to work with, you know, a chemical engineer, an electrical engineer, for whatever project, you know, in ways you may not think about previously, so … […] Because I think you have things to learn from different types of people, different types of students, students who come from different backgrounds (Siobhan, Final Interview).

Siobhan used her experience as a former learner of physics. For instance, she knew that students complained for having to take her course as part of their preparation to become engineers, and hence she shared with them her life experience. Having worked as an engineer before starting her doctorate, she hoped that her perspective on the learning of physics could serve as an explanation for the students as of why they needed to learn about electricity and magnetism as part of their preparation to become chemical engineers.

Throughout the researcher's discussions with her, Siobhan believed that, as a teacher, she wanted to promote students' strong conceptual understanding of physics, their critical thinking skills, and an excitement about science in general, and physics in particular. She thought that students' excitement about physics came from their deep understanding of concepts, which she made her teaching priority as expressed in this quote:

> But the best part is probably that "eureka" moment. If you sometimes see that with the student, in their face, you can see when they finally understand something. Something that really seemed impossible to them, and then you come at it from a different angle, and then you look at it in a different way, and another way, and another way, and finally you find something that makes sense to them, and they have that "eureka" moment. That's great! (Siobhan, Final Interview).

She strived to explain the physics concepts to her students and did not concentrate much on the mathematical manipulation of equations. Her main goal was to lead the students into acquiring habitual scientific thinking skills which she explained as follows:

> I really want my students to have a deeper understanding of the subject. Not just learning facts, but have some understanding of the underlying Physics. Why does this happen? Why is this so? And the thing with Physics is really then to be able to translate that from some situation into something numerical that you can calculate. And that process is harder, and maybe that is already beyond what the level I'm teaching right at the moment, but trying to get my students to understand where things come from. […] Ideally, I would also like to have my students be able to think a little more like scientists, be able to understand the scientific method, and also their beliefs about science. In today's age, everything is built on technology and technology itself is built on science, and it's good to understand something that's going on inside that box and not just have a black box, not knowing what it is (Siobhan, Final Interview).

Even though she initially informed the researcher that she perceived herself as a scientist-teacher, Siobhan declared in the first interview that she "tilted more towards teaching". She enjoyed talking with her students about their career goals, or knowing she had a positive impact on their future, for instance by writing references on their behalf. She perceived her role as instructor of a large course to be one of a resource for knowledge, a person who facilitated students' understanding. She considered she was not important in the process of learning because she just guided the students in the right direction, but that the students were the active participants in learning. Finally, Siobhan perceived herself to be a learner for whom teaching meant "re-learning". This viewpoint referred to two aspects: one connected her teaching with her perspective, as a former student, of the material she taught. By this, she meant that as a teacher, she had to re-learn physics notions that she already knew at an advanced level, in the same way her students did. The second aspect referred to her perception of herself as a learner of teaching when she said, "I feel really like I am a learner when it comes to teaching. I am

still in the learning stage, and I'm just trying to improve and use those resources that are open to me […]" (Siobhan, Final Interview).

Despite her declaration to be a learner of how to teach, Siobhan had minimal investment in this type of learning throughout her participation in the program. Although Siobhan asked for the researcher's advice and engaged in discussions with her regarding her own teaching, she did not change her teaching approaches during her involvement in this program. Her long-time and regular use of peer instruction, demonstrations, and online forums, along with her busy and productive schedule as an academic researcher, were most likely important impediments for her implementation of new teaching strategies. For instance, she admitted that the incorporation of new instructional methods would represent a major time investment on her part when she said,

> At some point, I don't want to focus my time and efforts too much on the teaching strategy. At some point I've got to come back to the actual material. And having limited time, and also if you try too many different things, it can become a bit of a hodge-podge. And, you know, you want to have some kind of consistent method. So yeah, I think that's my… I mean the Interactive Lecture Demonstration goes together with the Peer Instruction. It's just the Peer Instruction way of doing a lecture demonstration. And something like, let's say the case study or the service learning, it's a big investment on my side, in terms of time and effort (Siobhan, Final Interview).

Throughout the program, the researcher examined and explored Siobhan's attitude toward participation in the program. From participating in the workshop, Siobhan considered that she learned many interesting and useful things about students. She mentioned that she was impressed to learn about her students' ways of thinking and learning, how they grew up, and their life experiences. She added that initially she tended to have a more standardized view of her students and that from what she learned from the workshop, she positively changed her perspective about them. As a result, she understood that teaching meant "identifying with the student". While she had few criticisms related to one workshop session dedicated to the organization of PowerPoint presentations used

for teaching, she mentioned that the workshop sessions clarified her understanding of Bloom's taxonomy and its relevance to the practical aspects of teaching and learning, enabling her to make connections between theory and practice.

During all workshop sessions, all workshop mediators made clear that students needed to know in advance the central course objectives, mainly from the syllabus, and that those had to be connected to the teaching strategies and finally, with the methods of assessment. Hence, establishing the major course objectives from the beginning of the course was an important issue discussed in the workshop. As a result of her participation in the workshop, Siobhan made no changes in terms of including the course objectives in her syllabus. Nevertheless, at the end of the program, she admitted she started to include course objectives in the syllabi she was preparing for the following academic year. This resulted from her close interaction with the researcher throughout the program. About course objectives she said:

> I never really thought in terms of objectives before the workshop. I was thinking in terms of material. I think this is what a lot of, especially in science, what a lot of lecturers and professors do. They think about the material and how to get the material over to them instead of thinking about "What change do I want to make in my student?" We discussed this a lot in the workshop. […] Before that I've never even verbalized in any way what my objectives were. One thing you asked me to do, I think before the workshop and again when we got started on this part of the program, was to actually write down my course objectives. And that helps you focus, it does (Siobhan, Final Interview).

Siobhan did change her teaching based on her viewing of the videotapes. For instance, she observed that she was turning her back to the students when she pointed to things projected on the screen and, in turn, she mentioned she would use the mouse pointer in the future to avoid turning her back to the class. Regarding her use of PowerPoint slides, she commented that she would not include too many illustrations in her slides, but rather she would draw them on the board, considering that students did not like her complete reliance on PowerPoint images and maybe they thought of her as

"lazy". Also, she reflected on the amount of time she allowed students to work on problems or conceptual questions included in the peer instruction exercises. All these led Siobhan to the refinement of her teaching methods, as observed throughout the program. In other words, toward the end of the program, Siobhan managed to incorporate in her teaching all these changes that she commented upon during her discussions with the researcher. Furthermore, while watching the videotapes, Siobhan paid attention to students' engagement. For example, after watching her most static class, she commented how sedentary students were.

When explicitly asked about her impression about watching the videotapes, she stated that it led her to have a better understanding of how she taught. Nevertheless, she declared in the final interview that the videotapes did not bring essential information about her teaching and that everything happened how she perceived it before watching the videotapes. She thought that she implemented peer instruction correctly and had no further suggestion. In general, she had a positive impression about her teaching after watching the videotapes, and admitted it made her "feel a little better" about herself. Despite receiving students' mixed comments about her teaching through the official university evaluations, she tended to rely on the positive impression left by the videotapes. Her impressions when viewing the videotapes of her teaching were

> I watched these two just this morning because I have to be forced into doing it. The funny thing was - I was saying before the tapes came on - I got these yellow sheets and they really did make me feel bad about my teaching reading them. That made me even more reluctant to watch the DVDs because it's just like being "punched to the gut", reading those things. And so I really put them off. And I've also been horribly busy, as usual. And then I watched them and was like, "They're really not that bad." (Siobhan, Final Interview)

Siobhan admitted that discussing with the researcher about her teaching had a positive influence on her practices. First, discussing about the inclusion of course objectives in the syllabus led her to actually incorporate them in the course document. Second, the investigator's suggestions to use lecture demonstrations as peer instruction

exercises, when she asked for students' multiple predictions or alternate explanations before performing the demonstrations, led to active student participation during the class. Third, she considered that listening to the researcher's opinion on student engagement and Siobhan's teaching practices after the researcher was among the students during Siobhan's teaching, added an insightful layer to their discussions. Her thoughts were:

> […] it was useful just to hear your impressions from actually sitting there with them. So one thing is a video, but it's actually very two dimensional. But actually hearing what you had to say about being there was also helpful (Siobhan, Final Interview).

Siobhan's participation in the program minimally influenced her teaching approaches and practices. She admitted that by participating in the program, she became more aware of details, referring to her mannerisms. Nonetheless, some of the effects of her participation in the workshop became evident only toward the end of the program, such as the incorporation of course objectives in her syllabus. Siobhan felt that her involvement in the program, through constant interactions with the researcher, brought her access to an objective impression about her teaching. While she considered students' evaluations to be subjective, she came to appreciate and make use of researcher's impartiality, as indicated by this comment:

> It's really nice to get an objective opinion about things, as well. I don't think the student feedback forms are very objective, I think they're exceedingly subjective. It's really about how much they like the subject, and how much they like getting up at that time in the morning, and all kinds of things. But I've found that this process has been much more objective, and that's very reassuring in ways. Thank you (Siobhan, Final Interview).

Siobhan started her participation in this program as a student-centered teacher, already implementing active learning methods in her large-enrollment class, and actively engaged in the scholarship of teaching and learning. For instance, at the beginning of the study, she was already engaged in content, process and premise reflection on instructional knowledge by describing the instructional strategies she used, taking into consideration

students' end-of-term evaluations of her teaching, and experimenting with alternative teaching methods and then comparing them (Kreber, 2006b). She also started her participation being already engaged in content and process reflection on pedagogical knowledge through her consulting of books on instructional methods and by administering inventories to students to probe their learning of specific concepts (Kreber, 2006b). Conversely, at the end of the program she admitted she did not trust students' end-of-term evaluations due to their lack of objectivity. Thus, she ceased to engage in process reflection on instructional knowledge. Very importantly, at the end of the study, Siobhan published an article on how to facilitate learning of Nuclear Physics in middle and high school, thereby showing her continued engagement in content and process reflection on pedagogical knowledge (Kreber, 2006b). However, the idea of publishing this article was not the result of her participation in the program, but an enterprise in which she had been engaged before she started to become involved in the study. Nonetheless, at the end of the program, Siobhan did not show proof of participation in more advanced forms of reflection on either instructional, pedagogical, or curricular types of knowledge. Finally, by corroborating data from interviews, field notes, and other sources, with Siobhan's updated resume, the researcher concluded that Siobhan's research agenda and her professorial status influenced the effects of her involvement in the program. For example, at the end of the study, she managed to publish a seminal research article in a very prestigious scientific journal, an accomplishment made possible only based on her intensive participation in research. Additionally, toward the end of the program she had a tenure review event scheduled, for which she had to demonstrate her engagement in productive research projects, as evidence of her contribution to the scholarship of discovery.

Siobhan had many valuable ideas about future faculty enrichment programs that targeted promotion of student engagement for instructors of large classes. For instance, she considered that a cross-disciplinary approach to such a program, in which workshop participants came from different departments, would bring a complex perspective on teaching enrichment. Also, she suggested that watching a course snapshot from a colleague present in the workshop and then discussing various teaching aspects from the

snapshot, would make the learning more focused on the teaching behaviors. She had important comments on the training of junior faculty, too. Thus, she suggested that new faculty should not have other responsibilities besides teaching during their first semester of their appointment, and should be mentored by a senior faculty member from the department.

Influence on Teaching Practices

Siobhan was videotaped four times during the program, and her teaching behaviors were analyzed and then evaluated by using the RTOP. Appendix J contains a summary of her engagement in reflective cycles during the program, and their influence on her teaching practices.

Siobhan was first videotaped when she used five multiple choice questions as peer instruction. The class had a fast pace and, apart from employing the five peer instruction exercises, Siobhan used direct lecture for the majority of time. She mainly used technology and occasionally the blackboard for graphic illustration of concepts. The direct lecture preceded the peer instruction exercises, such as important concepts were first presented to students and then students engaged in problem-solving and discussions about these concepts. She projected each question on the screen, explained it, and then let students work on the question before asking for their first show of flashcards. She then encouraged students to engage in conversation with their peers and subsequently, asked for their second show of flashcards. In the end, she did not ask the students to explain their answer choices, but explained the correct answer herself. Overall, outside the peer instruction exercises, Siobhan conveyed information and asked rhetorical questions for the majority of time. Students engaged in conversations with their peers during the peer instruction exercises, and occasionally they engaged in discussions with the teacher. While Siobhan allowed sufficient time for students' answers during the peer instruction exercises or when she asked few questions, the lecture had a fast pace and she never asked for students' feedback on the material. She used PowerPoint slides for the duration of the class, where she included the majority of diagrams and equations to which she pointed when necessary.

When Siobhan met the researcher to discuss the first videotape, the researcher suggested she included interactive lecture demonstrations used as peer instruction. Instead of actual demonstrations, the investigator proposed she used YouTube videos that contained demonstrations of course concepts. As such, researcher's recommendations indicated she played the video to a certain point when she stopped to ask students for predictions, which she would write on the blackboard as answer choices to the main question preceding the video. Then, after playing the video demonstration to the end, let the students discuss the possible answers before asking for their final answer choice. The researcher also suggested Siobhan asked students to give explanations for all possible answers involved before explaining the correct one herself. She seemed to like these ideas when they talked about them, but in practical terms, she ignored them and invited the researcher to videotape her second class when she used peer instruction again.

The second videotaped class had a faster pace than the previous one, when conveyed information preceded students' active participation in peer instruction. Siobhan used four multiple choice questions as peer instruction after she introduced the students with new concepts. She performed the peer instruction exercises in identical ways as during her first videotaped class. She allowed sufficient time for students to answer the questions and engage in conversations, while she gave the explanation for the correct answer in the end. She mainly used PowerPoint slides for the illustration of difficult concepts. While she asked only twice for students' feedback on the material she presented, they were not given sufficient time to ask their own questions and engage in discussions with her.

From videotaping the second class onwards, Siobhan's engagement in dialogue about her teaching became minimal. She informed the researcher she had a very busy schedule, being either away at conferences or at the main facility where she conducted her research projects. She did not spend sufficient time watching the entire videotape and then reflecting on her teaching, but rather jumped from one scene to the other minutes before she met the investigator. Subsequently, due to her minimal engagement in reflection on her teaching practices, Siobhan did not bring about any important comment about her teaching. She thought that her teaching did not need improvement, neither did

she open to researcher's questions and suggestions. Actually, she offered the first videotape to be used by the Center for Teaching and Learning as a perfect example of how to use peer instruction in a large class. Regardless of researcher's suggestions, Siobhan seemed to know exactly what teaching methods she would employ and when. From this moment until the end of the program, they stayed in touch via email, which the researcher used to send her YouTube videos to be used as interactive lecture demonstrations. Siobhan replied that she planned to use demonstrations during the last class of the semester, when she invited the researcher to videotape.

The third videotaped class also was very fast paced. Siobhan used only one multiple choice question as a peer instruction exercise, when students actively engaged in discussion with their peers. She employed peer instruction similar to how she did it in the previous videotapes. Overall, Siobhan conveyed information, explained mathematical equations, and used rhetorical questions for the majority of the class time. She relied on PowerPoint slides for graphic illustration of concepts. Throughout the entire class she asked several questions, but did not allow students sufficient time to answer them.

The fourth videotaped class was the last one of the semester before the final exam. Siobhan and the researcher did not meet to discuss the third videotape before videotaping the last one. This last class consisted mainly of interactive lecture demonstrations. The class as a whole was student-centered, with students actively engaged in making predictions, discussing possible answers with peers, or interacting with the instructor. Siobhan conveyed information for a minimal amount of time, being engaged in performing demonstrations or playing YouTube videos that contained demonstrations, which she received from the researcher. Overall, Siobhan described the demonstrations, asked students to make predictions, and then performed the demonstrations herself and engaged in discussions with the students. Following investigator's suggestions, Siobhan combined one demonstration with peer instruction, by asking students for several predictions, which she wrote on the blackboard as answer choices. She asked students for a first round of answers, performed the demonstration, encouraged the students to engage in discussion with their peers, and then asked for a

second round of answers. In the end, she explained the correct answer. She also showed two YouTube video demonstrations, stopping at times to ask for students' predictions.

RTOP scores

The RTOP scores of each videotaped teaching session are included in Table 3. They reflect the descriptions of the teaching methods employed by Siobhan, as presented previously. While the RTOP scores do not have a quantitative significance, they intend to illustrate in a more condensed form Siobhan's teaching practices throughout her participation in the program.

Table 3 - RTOP scores for the three videotaped course sessions taught by Siobhan.

	Course session #1	Course session #2	Course session #3	Course session #4
Lesson design and implementation	10	9	7	10
Propositional knowledge	17	18	16	15
Procedural knowledge	11	11	5	11
Communicative interactions	14	12	7	13
Student-teacher relationships	9	7	2	11
Total	61	57	37	60

Overall, Siobhan's RTOP scores stayed the same during the program. Nonetheless, one videotaped class was less student-centered than the rest due to her reduced engagement in discussions with the students and the use of only one peer instruction question. As a general rule, Siobhan managed to promote active student participation in her large physics class, but did not refine her ways of soliciting students' ideas or creating a community of learners. For instance, she achieved intellectual rigor of the notions she presented by following a prescribed procedural path of reasoning,

excluding alternatives and student argumentation. Most of the time, apart from the routine implementation of peer instruction exercises, the student voices were not heard in the class. Students had occasional questions to which she answered very briefly, without pursuing students' alternative explanations. She connected mathematics and physics content, but failed to connect them fully with the real world applications.

To summarize, throughout the program Siobhan made constant use of peer instruction, which she employed routinely in all videotaped classes. She had a personal way of implementing it, by using flashcards and giving the explanation for the correct answer herself. She did not ask for students' explanations of their answer choices, despite researcher's constant recommendations to do so. Thus, while she promoted active student participation in her class, Siobhan was still a novice user of active learning methods. She also used interactive lecture demonstrations during one class, when she incorporated some of author's suggestions and teaching materials. Overall, Siobhan did not transform her teaching practices during her participation in the program, most likely due to her minimal engagement in reflection and dialogue about her teaching. Moreover, she was convinced her teaching methods were just right with regard to active student participation, despite receiving unsatisfactory end-of-term student evaluations.

Summary

Although Siobhan recognized herself as a scientist-teacher, she admitted she had an inclination toward teaching. She attended teaching conferences in her field, read books on new teaching methods, and experimented with alternative teaching strategies. Thus, she reflected on her teaching and was concerned about her students' learning. At the time the study started, she had taught a large class for two semesters, when she experimented with several teaching methods. She routinely employed peer instruction and online forums and occasionally incorporated interactive student demonstrations in her large class. She was a novice student-centered teacher and her main teaching goal was to promote students' conceptual understanding of physics and to facilitate the building of students' abilities to work in teams.

Siobhan's participation in the program did not transform her approaches to teaching or her teaching practices. Moreover, due to her change at the end of the program in interpreting students' end-of-term evaluations as subjective, she did not engage in process reflection on instructional knowledge. At the time this study was conducted, she was entrapped in a very demanding research enterprise, which led to the publication of her research in a major peer-reviewed scientific journal, a great accomplishment for a scientist. This required a considerable amount of time, substantial intellectual effort, and significant energy. Meanwhile, she was preparing to renew her academic status with the University. As a result, she had limited resources to devote to her teaching. While she made every effort to grow as a teacher, for instance by writing papers on how to teach physics, she most likely did not have the necessary time to reflect and discuss about her teaching.

Cross Case Analysis

Introduction

The cross case analysis was organized to inform the three research questions. Table 4 summarizes the emergent themes from the three case studies. The first section describes participants' conceptions about teaching large classes before becoming involved in the program, describing their beliefs with which they entered into the program. The second section reports the influences of the program on participants' teaching approaches. Finally, the third section reports the effect of taking part in the program on participants' teaching practices, as observed in their classrooms.

Table 4 - List of emergent themes from the case studies.

Conceptions about Teaching Large Classes • Academics applied personal experience as former learners to reflect on student learning. • Academics aimed to promote students' conceptual understanding and their understanding of science. • Academics believed that questioning facilitated class interactions among students and between students and the teacher. • Academics held preformed ideas about students. • Academics perceived the large number of students and the physical setting, as major constraints when they taught a large-enrollment course.
Influences of the Program on Participants' Teaching Approaches • Academics focused on the social aspect of student learning.
Influences of the Program on Participants' Teaching Practices • Partaking in the workshop facilitated learning new teaching methodologies and how student learn. • Watching the teaching videotapes facilitated participants' attention to student engagement and personal mannerisms and led to the refinement of teaching methods. • Watching the teaching videotapes bolstered participants' confidence in their abilities to employ active learning teaching methods. • Engagement in dialogue about teaching led to the incorporation of sophisticated active learning methods, which had a positive effect on student engagement.

Conceptions about Teaching Large Classes

Study participants entered the program with various degrees of experience in teaching large-enrollment classes. For instance, Adrian had thirteen years of experience in teaching large classes, while Siobhan taught large classes for only two semesters and John never taught a large class. Nonetheless, all of them applied their experience as former learners of their subject matter when they reflected on their students' learning. For instance, Adrian realized that during his early years as learner, he "responded" better to those teachers who were excited about what they were doing. John remembered himself when he first started to learn advanced chemistry, and that he learned best from those teachers who treated him as a "colleague on a journey of discovery". Siobhan brought her

learning experience as an engineer before she started her doctoral work to the teaching of her physics classes for engineering majors.

All three participants had as a common teaching goal: their students' conceptual understanding of the subject matter. Adrian's main goal was to dispel students' misconceptions about science, which prepared them to understand human evolution and race. John focused on his students' understanding of chemistry concepts and he designed the course assessments with this goal in mind. Siobhan wanted to create dilemmas in her students' ways of thinking in order to break down students' preconceptions, which finally led the way to conceptual understanding. All three concentrated on teaching what science really was, how it worked, and how scientists thought.

Participants believed that questioning promoted class interactions among students and between students and the teacher. Adrian facilitated a discussion based on the results of the science-evolution survey he administered during his first class, which prepared the students for the most advanced anthropology concepts. He also routinely asked questions at certain points during his lectures, even though they stimulated the active participation of only a few students in the class. John mentioned that he questioned his students routinely during his teaching. Siobhan was a regular user of peer instruction who also claimed that through this method she opened communication pathways between her and the students and as a result, questioning was a constant component of her teaching.

Participants held preformed ideas about students. For instance, both Adrian and John believed that students who occupied the front rows of the auditorium were more interested in and more engaged with the subject matter than those sitting in the back rows. On the other hand, Siobhan thought that the majority of students in her class were not genuinely interested in physics, but that they chose engineering as a financially secure career path and hence they disconnected easily from the subject matter.

All three participants perceived the large number of students and the physical setting, as major constraints when they taught a large-enrollment course. Adrian believed that the large number of students was a great impediment in engaging them all and for using in-depth assessment methods. While John foresaw that he could not establish a direct interaction with a large number of students, Siobhan complained that this

characteristic impeded the close contact between student and teacher outside class, and hindered the inclusion of experiments as part of the lecture. Regarding the physical setting of a large class, Adrian was convinced that it was impossible to engage students who sat in the back rows of the auditorium, and John thought that he could not establish a relationship with students in the back rows because he could not see their facial expressions, could not hear them, and hence could not directly communicate with them.

Influence of the Program on Teaching Approaches

As a result of their participation in the program, academics focused on the social aspect of student learning. Through the virtue of the design of the program, participants were guided to concentrate their attention on their interactions with students and those among students. Moreover, participants started to put student learning into a perspective more intimately connected with their teaching and the social environment.

Influence of the Program on Teaching Practices

Partaking in the workshop facilitated learning about new teaching methodologies and how students learn. Adrian believed that in the workshop he learned new teaching methods and became aware of students' learning processes. John thought that he learned new teaching methods and that, when he took the learning style questionnaire during the workshop, it gave him the idea to administer a similar questionnaire to his students to evaluate the diversity of learning styles in his class. Siobhan remarked that she learned about this students' generation and how these students learned. She also mentioned that she understood how the levels of Bloom's taxonomy can connect learning objectives and pedagogy with methods of assessment.

Watching the teaching videotapes facilitated participants' attention to personal mannerisms and student engagement and led to the refinement of teaching methods. In the initial phase of videotape watching, all participants concentrated on their personal mannerisms. Beyond this phase, they focused more on their teaching practices and the degree of students' active participation. They all observed certain aspects of their teaching which they considered imperfect and consequently, this led to the refinement of

their teaching techniques or behaviors. For instance, initially Adrian observed he had a sarcastic smile that had a distancing effect on students. In subsequent stages, he noticed the various levels of student engagement throughout the classroom and practical aspects of his teaching, namely that PowerPoint slides that contained colored answer choices for peer instruction questions did not project well. Very importantly, he made the observation that when he invited students to explain their answer choices for peer instruction exercises, he should have invited few students to explain their choice of the incorrect answers before inviting other students to explain their choice of the correct answer.

John observed his habit of spending a long time with the computer set up or bending over the Smart Board to write important notions or draw diagrams, which disconnected him from the students. He also observed that when a student asked him a question, he approached the student to answer the question, without repeating the question for the entire class. When he implemented peer instruction exercises, he observed he needed to allow students a shorter time for their first round of answers, and allow them longer time to engage with peers and discuss possible alternatives before the second round of answers. Very importantly, his concentration on student engagement during the peer instruction exercises led to the refinement of this technique, namely to hide the frequency distribution of the first set of answer choices, thus eliminating any bias for the second set of answer choices.

After watching the videotapes, Siobhan initially noticed her mannerisms. In later stages, she had the impression that students were sedentary and assumed that this was caused by the long time she allowed students to engage in discussions with their peers during the peer instruction exercises. As a common note among all three cases, watching the teaching videotapes had a bolstering effect on participants' confidence in their abilities to employ student-centered teaching methods in a large class.

Engagement in dialogue with the researcher about teaching led to incorporation of sophisticated active learning methods, which had a positive effect on student engagement. Some of the effects were: Adrian implemented peer instruction, John employed interactive lecture demonstrations with the aid of YouTube videos and blocked the first set of answer choices to eliminate bias, and Siobhan used interactive lecture

demonstrations as peer instruction exercises and made use of YouTube videos for some of them. All these methods led to increased levels of active student participation.

Discussion

The present study explored the transformation of teaching approaches and behaviors of science academics involved in a transformative professional development program. The study showed that participants, as a result of their engagement in reflective cycles triggered by watching their teaching videotapes, minimally changed their teaching practices to incorporate active learning strategies, whereas their teaching approaches remained unchanged. As supported by previous research (Apte, 2009; Lange, 2004), for the development of a new perspective leading to the change of both teaching approaches and practices, the researcher acknowledges the possibility of participants' engagement in a phase of retreat from exploration or dormancy, when they dealt with the disorientation produced by the trigger events in the workshop. During this dormancy phase, participants declined the transformation of teaching approaches while experimenting with limited teaching practices learned in the workshop. By continuing to experiment with a multitude of student-centered teaching methods, connecting with peers in a supportive institutional culture, maintaining engagement in reflective cycles, and only when these varied approaches to learning about teaching indicated positive outcomes, would they be more likely to continue to develop and test the transformed frame of reference. Lastly, in a phase of reintegration (Mezirow, 2000), participants are expected to develop new perspectives and to enact the newly espoused frame of reference, namely to recognize the adoption of new teaching approaches.

Another important aspect of transformative learning applied to the professional development of instructors takes into account the essential role of the continuously supportive departmental or institutional environment when they try new roles (Gravett, 2004). As such, the social climate of the institution should foster instructors' engagement

in critical reflection about teaching, by supporting, valuing, and rewarding learning about teaching. For instance, it is suggested that encouragement of instructors' involvement in research on teaching can be one mechanism by which the gap between valuing research and valuing teaching can be bridged (Cranton, 1994).

Finally, as suggested by Kreber (2001), graduate education in any discipline should allow for the synthesis between discipline knowledge and pedagogy, thereby leading to the formation of future academics that possess the knowledge about education theory and the disposition for engagement in the scholarship of teaching. Moreover, as observed in other countries (Kreber, 2006a), higher education policy should change as to include mandatory involvement of teaching faculty in sustained, institution-wide professional development programs.

As Carusetta and Cranton (2009) initially suggested, placing college faculty as adult learners engaged in reflective learner-centered learning leads to making a first step toward a reform in higher education. Generally, colleges and universities engage faculty in professional development through in-service workshops. To truly engage academics in the scholarship of teaching, it is important to help them develop reflective teaching skills which will enable them to explore new ways of thinking about teaching without the constraints imposed physically or conceptually by the institution. When college faculty actively develop a deep understanding of their roles as educators, institutions of higher education will become able to engage people in critical thinking, creative leadership and innovation.

CHAPTER V
CONCLUSIONS AND IMPLICATIONS

This study was based on transformative learning theory (Mezirow, 1978, 1981, 1990, 1991, 2000, 2009) and the emergent model of the scholarship of teaching and learning (Kreber and Cranton, 2000). Three academics participated in a two-day summer workshop focused on the incorporation of active learning in the teaching of large-enrollment science courses, followed by a series of three to four videotaped critical reflection cycles with the researcher. Participants' engagement in transformative learning and their enactment in regards to student-centered learning as well as how this approach influenced the teaching of these courses were explored.

Conclusions

Academics' Conceptions about Teaching Large Classes

The literature on teaching in general, and in higher education in particular, describes teaching as a developmental process in which one can move from simplistic abilities and beliefs to more integrated skills and conceptions. For example, Sherman and colleagues (1987) described a four stage model of acquiring teaching excellence, through which academics moved from an initial stage of teaching as telling, through teaching as leading, then teaching as transmitting knowledge, and finally to teaching as a complex interaction among students, content and teacher actions. Hence, in this study participants' conceptions about teaching large-enrollment courses were explored with the intention to evaluate their attitudes and beliefs about teaching such courses before and after they became involved in the program. Thus, as transformative learning researchers assert, "to claim that transformative learning has occurred there must be evidence of change" (Pohland and Bova, 2000, p. 145), and to realize the influence of the participation in the program and the degree of change, a starting point needed to be established.

The three participants in this multiple case study were different in their conceptions about teaching large courses. Adrian was perceived as a teacher-centered academic with a long experience in teaching large classes, Siobhan as a student-centered instructor with limited teaching experience, and John was in principle a student-centered teacher who had never taught a large course. Having different orientations and levels of teaching experience, they all had preformed ideas about students in a large course and believed that the large number of students and the physical setting were major impediments to student engagement. Despite these perceived impediments, these three instructors had similar goals for their students that were based on their own past experiences in these types of courses. Each believed that their major teaching goal was students' conceptual understanding to which questioning was the major means of facilitating class interactions.

At the beginning of the study, all three participants were actively engaged in the development of the scholarship of teaching and learning, mostly by reflecting on their instructional and pedagogical types of knowledge. Nevertheless, Kreber (2005) found that science instructors who espoused student-centered, conceptual change beliefs about teaching tended to engage in premise reflection (e.g., critical reflection) regardless of their level of teaching experience (Kreber, 2005). Based on these previous research findings, only two participants in this study, John and Siobhan, held student-centered teaching conceptions and consequently were found to be engaged in premise reflections from the inception of the study. Adrian, the more experienced teacher of large classes, adhered to teacher-focused pedagogy and expectedly, engaged in lower levels of reflection. These findings agree with Kreber's study (2005) that concluded that teacher's situation-specific (i.e., about large-enrollment courses) beliefs about teaching play an important role in reflection.

It is important to note that the study participants were all expert scientists, who were *a priori* considered to adhere to positivist epistemologies and hence, who strongly relied on evidence in the process of learning. The watching of their teaching videotapes was intended to serve as evidence of their teaching and hence, once reflection cycles initiated, to facilitate transformative learning about teaching. Very importantly, as

iterated by Kreber and Castleden (2009), because learning about teaching is by nature a communicative process and only rarely instrumental, it may be perceived as a challenge for instructors from fields where more instrumental ways of inquiry are dominant. Moreover, it was shown that academic teachers in the hard sciences (e.g., physics, chemistry) were generally concerned with the transmission of instrumental knowledge, while those in soft fields (e.g., literature, philosophy) focused more on communicative knowledge (Cross, 1991). These research-based considerations need to be accounted for when academic science instructors become engaged in transformative learning experiences aimed to facilitate the transformation of their teaching toward incorporation of student-centered approaches and practices.

Academics' Engagement in Reflection and Dialogue about Teaching

All the participants' engaged in reflective cycles, which comprised critical reflection induced via dialogue and videotape watching, however, they did not all reach similar reflection levels. The experienced instructors, Adrian and John, became involved in the reflective processes with various effects on their teaching, while the novice teacher Siobhan avoided engagement in the reflection cycles. This finding agrees with previous research that showed an increased tendency of experienced faculty to engage in reflection about teaching (Kreber, 2005).

Another important finding reported by Kreber (2005) suggested that when learning about teaching, instructors needed to begin with the premise that reflection was necessary in order for their learning to be more meaningful, namely to be concerned with *why* they teach rather than with *how* or *what* to teach. The two study student-centered instructors, John, an experienced academic, and Siobhan, a novice one, became involved in the study as active participants in premise reflection. Accordingly, John demonstrated an increased engagement in reflection throughout the duration of the study, while Siobhan refused to reflect on her teaching. One explanation may be that, for instructors with similar teaching orientation, the level of teaching experience in general rather than the experience in teaching large science courses, contributes to their engagement in reflection. As Kreber (2005) asserted, the more experienced student-centered instructor

reflected deeper on his teaching than the novice one. Why Siobhan did not reflect on her teaching could be the result of multiple factors. For instance, it is important to note that Siobhan's academic status and active involvement in research may have contributed to this outcome. For instance, Hubball, Collins and Pratt (2005) pointed to the fact that due to their busy schedules, instructors may decline engagement in formal reflection activities and may feel they are pushed into excessive reflective pursuits. They also identified disproportionate time allocation and varying cultural norms as barriers to engagement in reflection about teaching, arguing that there are no specific techniques that facilitate reflection.

Based on Mezirow's (1981, 1991) seven hierarchical levels of reflective learning, one study (Liimatainen, Poskiparta, Karhila and Sjogren, 2001) explored the development of reflective learning by using video recordings to stimulate recall during interviews, and identified non-reflectors, reflectors who mostly focused on content and/or process reflection, and critical reflectors who engaged in all three types of reflection. Throughout this study, Siobhan avoided engagement in reflection and hence, was considered to be a non-reflector characterized by the absence of transformations and presence of barriers that discouraged and inhibited transformative learning. On the other hand, John demonstrated to be a critical reflector who participated in all levels of reflection throughout the duration of the study, which led to his engagement in profound transformative learning. This can be also explained by his orientation to student-centered teaching. Adrian experimented with a new teaching method during the study, which showed his involvement in premise reflection on instructional knowledge. Yet, due to his skepticism, resistance to change, and teacher-centeredness, he was considered to be at the borderline between a non-reflector and a reflector. According to Liimatainen and coworkers (2001), he was considered borderline because he did not show to possess conceptual, judgmental, and discriminant reflectivity regarding the incorporation of active learning methods in his teaching.

McAlpine and Weston (2000) found that teachers who were engaged in reflection that led to improved teaching encompassed strong cognitive engagement, such as was the case with John. The same study (McAlpine and Weston, 2000) suggested that there were

also teachers like Siobhan who were unable to engage in reflection due to lack of motivation, lack of knowledge about teaching, and fear of taking risks. Moreover, they argued that there were teachers like Adrian, who minimally engaged in reflection, but could not commit to improving their teaching due to lack of knowledge about teaching, fear of risk taking, an inability to successfully carry out decisions, or certain personality characteristics. As such, they argued that the processes of reflection could fail to be initiated or fail to be completed due to a multitude of personal, contextual, and/or social factors.

Because dialogue has been long seen as an essential component of transformative learning, and as a discipline of collective thinking and inquiry, leading finally to transformation of organizations (Argyris and Schön, 1978; Isaacs, 1993; Schein, 1993), and establishing relationships, researcher's engagement in dialogue with all three participants through openly sharing information was an important aspect of the research. Nonetheless, it may be possible that study participants did not engage with the researcher in an authentic relationship. For instance, previous studies (Eisen, 2001) identified a peer dynamic important to transformative learning, in which equalization of power between participants in dialogue led to the development of trust, learner autonomy, and perspective change. To this end, it is important to realize that the study participants were expert scientists and successful academics, while the researcher was a doctoral student that represented the Center for Teaching and Learning at the University. Hence, how participants perceived the researcher may have influenced how they interacted with her throughout the study and thus, how they engaged in transformative learning about teaching. Nonetheless, this study adhered to previous research which showed that reflection and dialogue should continue to be integral parts of professional development programs, which provide ongoing guidance and support for reflective teaching.

Influence of the Program on Academics' Teaching Approaches

As a result of their participation in this study, the three science instructors became more aware of the class interactions among students, and between the teacher and the students. However, findings reported here are limited by the comments participants chose

to make within the context of the interviews. It is important to acknowledge that, as observed by others (Argyris, 1991; Argyris and Schön, 1978; Gravett, 2004; Kreber, 2005), espoused teaching beliefs revealed through interviews did not frequently correspond with academics' beliefs in action, or to their teaching practices. For instance, as argued elsewhere (Kreber, 2004), in an interview situation between an educational researcher or an institutional professional developer and instructors, the latter may feel a sense of vulnerability or inferiority due to how they are perceived. This may come from the fact that the science instructors possessed mostly experience-based knowledge about teaching as opposed to theoretical and research-based teaching knowledge, due to a lack of preparation in how to teach. They may have been hesitant to reveal to the researcher what they did not know.

Based on the analysis of the data, the study participants did not change their teaching approaches at the end of the program. If they started as teacher-focused or student-centered instructors, they continued to hold onto the same teaching orientation until the end of the study, regardless of the degree of change in their teaching practices. One explanation may come in accord with Lange (2004), who suggested that when information was discrepant with a long-held valued frame of reference, participants retreated from their exploration and returned to their previous assumptions. This defensiveness may be seen as a stabilizing response, leading to a time of retreat or dormancy (Apte, 2009), and should be acknowledged by faculty developers. On the other hand, Postareff and colleagues (2007, 2008) showed that approaches to teaching changed slowly, and it may be possible that this too might be true in these cases.

Influence of the Program on Academics' Teaching Practices

Throughout this program, Adrian and John changed their teaching practices, while Siobhan did not change hers, as evaluated from teaching videotapes and RTOP scores. Siobhan's RTOP scores stagnated throughout the program and this was interpreted as resistance to change, while Adrian and John's increased RTOP scores showed incorporation of active learning. It is important to note that a change in teaching practices did not necessarily correlate with a change in teaching approaches. As in Adrian's case,

for example, he changed his teaching behaviors to incorporate peer instruction, but continued to remain a teacher-centered instructor. On the other hand, John showed the most apparent transformation of teaching practices, probably due to his student-centeredness and long teaching experience, while Siobhan did not change her teaching practices despite her being a student-centered teacher. As outlined by a previous researcher (Kreber, 2006b), a change in teaching practice may take place as a result of engagement in transformative learning and depends on a combination of other factors, such as personal (willingness to change), social (support for change), and contextual (institutional constraints).

As Gravett (2004) showed, teaching development aimed at facilitating change in teaching practice demanded transformative learning and involved engagement in critical reflection and dialogue. Accordingly, this study showed that, when professional development support was continuously provided through facilitation of engagement in reflection and dialogue about teaching, teaching practices were the first to change. Most probably, when professional development support continued to be provided to instructors for a longer time and by using multiple strategies, changes in teaching approaches would follow at a later stage.

Implications for Designing Transformative Professional Development for Higher Education Science Instructors

Based on findings from this study that come in accord with previous research, one recommendation for designing transformative professional development for higher education science instructors is to consider their involvement in long-term programs. To promote transition from teacher-centered to student-centered teaching approaches, a longer engagement in reflective and dialogic cycles needs to be provided. Since research does not indicate a specific time range associated with effective programs, this study shows support for activities that spread for over one academic year. For instance, Jungst,

Licklider and Wiersema (2003) showed in a three-year study of seventy-four faculty that participation in ongoing, long-term professional development activities that included a series of workshops accompanied by biweekly faculty meetings with developers, led to successful implementation of active learning techniques. In particular, they argued that voluntary participation by faculty, management of a strong expertise in education and in leading effective professional development by facilitators, employment of active learning techniques during workshops to provide teaching models, and continued institutional support, were essential for successful transition of faculty to student-centered teaching.

Another suggestion comes directly from the study participants. For instance, formal learning experiences such as workshops may not represent the sole foundation for teaching knowledge in effective transformative professional development programs, but also collaboration with both peers and professional developers (Buehl and Fives, 2009; Gravett, 2004). For instance, Gravett (2004) showed that isolation of participants upon completion of a professional development program that involved engagement in critical reflection on teaching, represented an obstacle in the process of change of teaching approaches. This confirmed findings reported previously by Yorks and Marsick (2000) on transformative learning in an organizational context, that identified the important role of collaboration in sustaining changes within an organization.

While self-reflection and enactive learning experiences, such as teaching with a new method and reflecting about this new teaching, play important roles in learning about teaching, vicarious learning experiences can also serve as valid sources for instructors' pedagogical knowledge. Observing expert teachers teach and being observed teaching by those same peer expert teachers, followed by interactive feedback and reflective discussion, would also prove effective. Moreover, all participants in this study proposed that future programs needed to include academics from different disciplines in order to offer a broader perspective on teaching approaches. As such, a cross-disciplinary professional development program may provide the participants with different views and understandings of teaching and learning. For instance, instructors from the soft fields, more inclined toward communicative learning, may serve as learning models for the science academics.

Further Questions for Investigation

It is important to note when interpreting the findings of this research that, due to the voluntary nature of partaking in this study, participants were enthusiastic science instructors who were concerned about teaching and learning. Thus, this group may or may not be considered representative of science academics that teach large-enrollment introductory classes in general. Hence, as a result of this study, the researcher is in the position to draw limited conclusions about the likelihood of such instructors to change their teaching practices as a result of participation in the abovementioned program. A larger study that included a more diverse spectrum in terms of participants' teaching experience and orientation, subject area, and levels of teaching training should be conducted.

A longitudinal study investigating whether, and if so how, academics involved in reflection on teaching in collaboration with a professional developer, changed their perceptions about teaching and learning is recommended. For instance, a longitudinal study involving intense engagement in reflection and dialogue among academic peers with different teaching orientations and experiences, and with experienced professional developers, may further our understanding of ways in which engagement in long-term reflective teaching plays a role in the transformation of both teaching practices and approaches.

Initially, Mezirow (1978, 2000) described ten steps that precede perspective transformation, which were empirically identified through a recent quantitative study performed with undergraduate business students (Brock, 2010): 1) occurrence of a disorienting dilemma; 2) self-examination; 3) recognition of personal discontent; 4) exploration of options for new roles; 5) critical assessment of assumptions; 6) provisional trying of new roles; 7) planning of a course of action; 8) acquisition of knowledge and skills for implementing new course of action; 9) building of competence and self-

confidence in new roles; and 10) reintegration into personal life on the basis of conditions dictated by the new perspective. It may be valuable to the entire body of research on transformative professional development in higher education to explore if instructors follow these steps or if there is a different trajectory when they transform their teaching. A longitudinal qualitative study involving a large number of participants from multiple and varied contexts may offer an insightful perspective of academics' transformations as learners of teaching.

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APPENDICES

APPENDIX A

Workshop Outline

Day 1 (July 14, 2009)

8:00 – 8:30 Continental breakfast

8:30 – 9:30 Introduction

Introduction to the workshop

Participant introductions

Faculty Success – two venues

Circle of Learning: Conceptual Model Combining the Bloom and Anderson Revised Taxonomy and including Felder's Learning Styles

Workshop environment

Testimonial

9:30 – 9:45 Break

9:45 – 10:35 Session 1: The Student Perspective

Demographics of millennials

Distribution of majors and degrees

General millennial characteristics and influences

What do we know about the characteristic of today's students? (group exercise)

The students' perspective on themselves (video presentation)

Key motivations

What conclusions can we draw from this picture of students? What are the challenges that you face as teachers (brainstorming)

10:35 – 10:45 Break

10:45 – 12:00 Session 2: Felder's Learning Styles Dimensions

Creating faculty learning styles profile
Understanding today's student learning profile
Awareness of differences between faculty and student learning styles
Creating pedagogy around student learning styles (group exercise)

12:00 – 1:00 Lunch

1:00 – 2:00 Session 3: Case Studies I – Learning Styles
Interactive Lecture Demonstrations and Experiments
ConcepTests/Peer Instruction/Think-Pair-Share
TA training

2:00 – 2:15 Break

2:15 – 3:30 Session 4: Applying Felder's learning styles dimensions and Bloom and Anderson's taxonomy of learning to create enriched learning experiences
Presentation of Bloom and Anderson's taxonomy
Presentation of conceptual model
Exercise in course redesign matching pedagogy and assessment to learning level objectives (team exercise)

3:30 – 3:45 Break

3:45– 4:30 Session 5: Case studies II – Levels of Learning
Case study teaching
Online Forums, Blogs, and Wikis
Inquiry Based Labs

4:30 – 5:00 Conclusion of Day 1
Questions and answers

Planning for Day 2

Evaluation of Day 1

Day 2 (July 15, 2009)

8:00 – 8:20 Continental Breakfast

8:20 – 9:30 Session 6: Enhancing the traditional method of lecturing to large lecture sections

Acting and speech coaching

9:30 – 9:45 Break

9:45 – 10:45 Session 7: Continued acting and speech coaching

10:45 – 11:00 Break

11:00 – 12:00 Session 8: Motivational PowerPoint Presentation

12:00 – 1:00 Lunch

1:00 – 2:00 Session 9: Case studies II – Comprehensive

JiTT – Just in Time Teaching/Quizzes

Service Learning/Project based learning

Active Learning

2:00 – 2:15 Break

2:15 – 3:15 Session 10: Enriching your course

Resources on Campus

Enrich your courses – focus on design elements: learning objectives, pedagogy, and assessment (individual exercise)

3:15 – 3:30 Break

3:30 – 4:30 Session 11: Sharing thoughts
Plan for course enrichment
Philosophy of teaching
Syllabus
Conducting action research (two types of success)

4:30 – 5:00 Conclusion of Day 2:
Questions and answers session
Continued Coaching
Closing Thoughts
Workshop Evaluation
End of workshop

APPENDIX B

Video-Stimulated Reflection Cycle

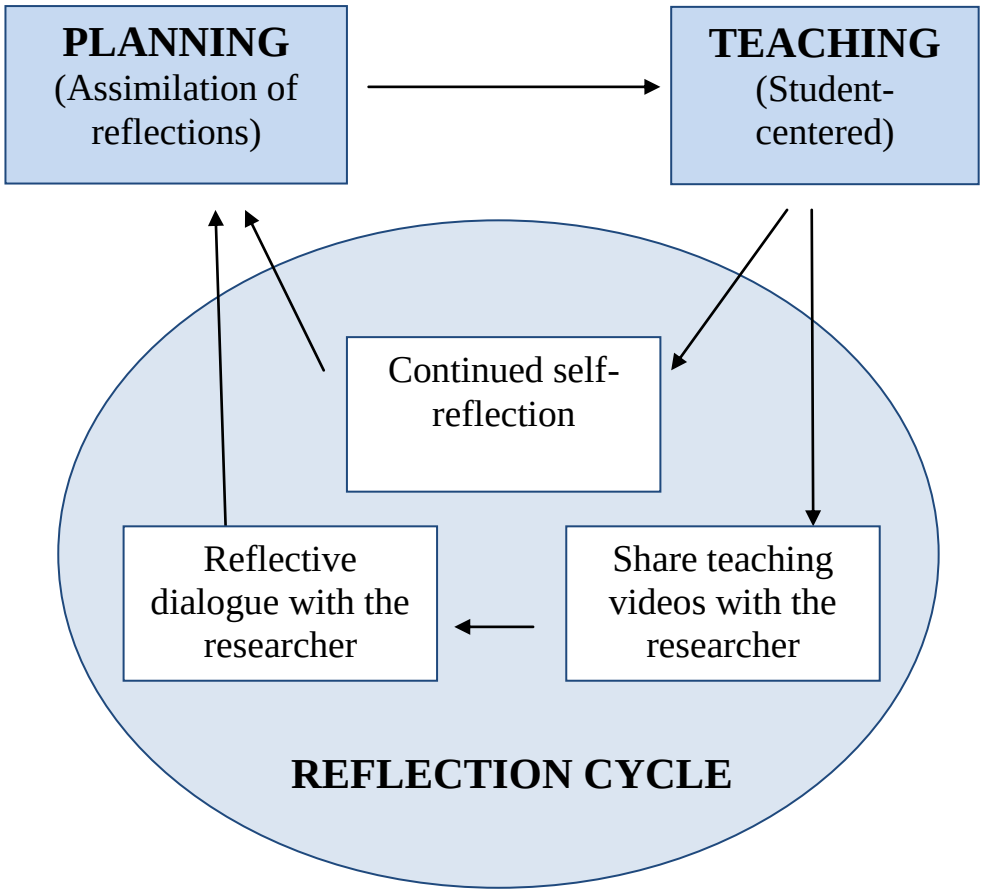

Figure 4. Video-stimulated reflection cycle (adapted from Lebak and Tinsley, 2010).

APPENDIX C

Stages of the Study and the Corresponding Data Sources

Study Stages	Data sources
Pre-program stage	1) Notes taken by the researcher after meeting informally with each participant prior to the workshop (Pre-Notes); 2) Participants' large-enrollment course syllabi for the large enrollment courses taught prior to attending the program (Syllabus); 3) Participants' statements of teaching philosophy (Philosophy); 4) Participants' reflection notes about teaching a large course (Reflection).
Program stage	5) Verbatim transcriptions of the initial interview (Initial Interview); 6) Notes taken by the researcher during individual meetings with participants (Post-Notes); 7) Verbatim transcripts of videotapes of course sessions, which include observer's field notes (Video); 8) RTOP scores of videotaped course sessions (RTOP); 9) Participants' course syllabi for the large-enrollment course(s) taught during the academic year 2009-2010 (Syllabus); 10) Other teaching artifacts (Teaching Artifact).
Post-program stage	11) Verbatim transcriptions of the final interview (Final Interview); 12) Participants' updated resumes (Resume).

APPENDIX D

Outline of Informal Conversation

The following are guiding questions used by the researcher in the informal conversation with the participants during the pre-program stage of the study.

1) What would you like to learn in the workshop?
2) Can you provide details about a typical large class that you ever taught? (i.e., student enrollment, etc.)
3) How do you see your role as instructor of a large class?
4) What is your teaching experience?
5) Have you been engaged in any form of teaching training?
6) How do you define “success” as a teacher?
7) How do you perceive yourself: as a teacher or as a scientist?

APPENDIX E

Outline of the Initial Interview

I appreciate your willingness to meet with me today. I would like to remind you that your identity remains strictly confidential and that I am truly seeking your honest view about this. This interview should take approximately 1 hour.

Questions about teaching context:

1) The purpose of this interview is to explore the way academics approach teaching in the context of a large-enrollment undergraduate science course. Answers to my questions in this context may be different to responses you might make on your teaching in other context or with other students. For this reason, I would like you to describe the context, such as the subject being taught, the course level, and the number of students you usually have in this class.

Questions about students' prior knowledge (modeled after ATI items):

2) What do you assume about the knowledge students possess about the subject? Do you start from the assumption that students have very little useful knowledge of the topics taught? Do you test your assumptions in any way? Can you give me an example?

3) How do you use students' existing knowledge on the subject? How do you relate students' existing knowledge with the new material covered in your course? Do you encourage students to restructure their existing knowledge in terms of the new way of thinking about the subject that they will develop? How? Can you give me an example?

Questions about the relevance of subject taught (modeled after ATI items):

4) How do you describe the subject to your students? How do you explain to your students the importance of the material you teach? Do you consider important to describe the subject in terms of the specific objectives related to what students have to know for formal assessment?

Questions about student-teacher interactions (modeled after ATI items):

5) How do you interact with your students in class? Do you engage your students in conversations about the topics they study? Do you provide opportunities for them to discuss their changing understanding of the subject? How? Can you give me an example?

6) Do you provide students with opportunities to ask you questions about the subject? How? Can you give me an example?

Questions about student-student interactions (modeled after ATI items) :

7) Do you engage students in conversations among themselves during or outside class? How? Why? Do you set aside some teaching time during the course, when students can discuss among themselves about difficulties encountered studying this subject? How do you engage students in discussion about difficult concepts in your course? Can you give me an example?

8) Do you provoke debate in your course sessions? Why? How? Do you use difficult or undefined examples to initiate debate?

Questions about course structure and pedagogy (modeled after ATI items):

9) How do you design your teaching of this subject? How do you teach this subject in general? How do you structure your course? Are your students aware of the course objectives and student learning goals? How? Do you present your students with facts so that students will know what they have to learn for this subject? Can you describe to me a representative course session?

10) Do you devote time during class to question students' ideas? Do you think it is important that a majority of teaching time be devoted to question students' ideas? Why or why not?

Questions about course assessment procedures (modeled after ATI items):

11) How do you know your students understood the material? How do you design the assessments used in your course? What are your goals when designing an assessment for this course? What do you feel your course assessments provide to the students?

12) Do you think assessments should reveal students' changed conceptual understanding of the subject? Can you give me an example of a learning objective and its corresponding assessment?

Questions about the role of the instructor:

13) What do you feel your role as an instructor of a large-enrollment course is? Why do you think your students should come to class?

14) How do you deal with questions that students have for you in class? Do you feel that you should know all the questions that students have on the subject?

15) As a teacher, how would you define success? How would you define success in general?

16) How do you perceive yourself: more as a teacher, or as a scientist?

Questions about the workshop:

17) What are your general impressions about the workshop? What did you find most useful for you as a teacher? What did you learn in the workshop? Are you willing to try any teaching techniques that you learned in the workshop? Why do you want to try them? Do you perceive any challenges to implementing these techniques?

18) I have finished with my questions now. Do you have any personal considerations regarding this course that we haven't discussed and you would like to share with me?

We are finished now. Thank you so much for spending your time to talk with me. Your input is going to be very valuable to the development of this project.

APPENDIX F

RTOP

Reformed Teaching Observation Protocol (RTOP)

Daiyo Sawada
External Evaluator

Michael Piburn
Internal Evaluator

and

Kathleen Falconer, Jeff Turley, Russell Benford and Irene Bloom
Evaluation Facilitation Group (EFG)

Technical Report No. IN00-1
Arizona Collaborative for Excellence in the Preparation of Teachers
Arizona State University

I. BACKGROUND INFORMATION

Name of teacher _____ Announced Observation? _____ (yes, no, or explain)

Location of class _____ (district, school, room)

Years of Teaching _____ Teaching Certification _____ (K-8 or 7-12)

Subject observed _____ Grade level _____

Observer _____ Date of observation _____

Start time _____ End time _____

II. CONTEXTUAL BACKGROUND AND ACTIVITIES

In the space provided below please give a brief description of the lesson observed, the classroom setting in which the lesson took place (space, seating arrangements, etc.), and any relevant details about the students (number, gender, ethnicity) and teacher that you think are important. Use diagrams if they seem appropriate.

III. LESSON DESIGN AND IMPLEMENTATION

		Never Occurred				Very Descriptive
1)	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	0	1	2	3	4
2)	The lesson was designed to engage students as members of a learning community.	0	1	2	3	4
3)	In this lesson, student exploration preceded formal presentation.	0	1	2	3	4
4)	This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	0	1	2	3	4
5)	The focus and direction of the lesson was often determined by ideas originating with students.	0	1	2	3	4

IV. CONTENT

Propositional knowledge

6)	The lesson involved fundamental concepts of the subject.	0	1	2	3	4
7)	The lesson promoted strongly coherent conceptual understanding.	0	1	2	3	4
8)	The teacher had a solid grasp of the subject matter content inherent in the lesson.	0	1	2	3	4
9)	Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.	0	1	2	3	4
10)	Connections with other content disciplines and/or real world phenomena were explored and valued.	0	1	2	3	4

Procedural Knowledge

11)	Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	0	1	2	3	4
12)	Students made predictions, estimations and/or hypotheses and devised means for testing them.	0	1	2	3	4
13)	Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	0	1	2	3	4
14)	Students were reflective about their learning.	0	1	2	3	4
15)	Intellectual rigor, constructive criticism, and the challenging of ideas were valued.	0	1	2	3	4

V. CLASSROOM CULTURE

	Communicative Interactions:	Never Occurred				Very Descriptive
16)	Students were involved in the communication of their ideas to others using a variety of means and media.	0	1	2	3	4
17)	The teacher's questions triggered divergent modes of thinking.	0	1	2	3	4
18)	There was a high proportion of student talk and a significant amount of it occurred between and among students.	0	1	2	3	4
19)	Student questions and comments often determined the focus and direction of classroom discourse.	0	1	2	3	4
20)	There was a climate of respect for what others had to say.	0	1	2	3	4
	Student/Teacher Relationships:					
21)	Active participation of students was encouraged and valued.	0	1	2	3	4
22)	Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	0	1	2	3	4
23)	In general the teacher was patient with students.	0	1	2	3	4
24)	The teacher acted as a resource person, working to support and enhance student investigations.	0	1	2	3	4
25)	The metaphor "teacher as listener" was very characteristic of this classroom.	0	1	2	3	4

Additional comments you may wish to make about this lesson.

APPENDIX G

Outline of the Final Interview

I appreciate your willingness to meet with me today. I would like to remind you that your identity remains strictly confidential. This interview should take approximately one hour.

The focus of this interview is on your considerations stimulated by the workshop, the reflections you had about your teaching as you reviewed the videotapes, and our interaction during the program. Throughout the duration of this interview, the term 'program' refers to your participation in the workshop and your engagement in reflections on teaching based on reviewing teaching videotapes and through our follow-up discussions.

Questions about teaching conceptions:

1) How many years have you been teaching?

2) Tell me about your beliefs about teaching. What does teaching mean to you? Describe me what you consider most important in teaching your subject.

Questions regarding teaching large-enrollment courses:

3) How many years have you been teaching a large-enrollment course?

4) What are your thoughts about teaching a large class?

5) How many students flunk your large-enrollment course? Have you thought why?

6) What would you like to see changed? Why?

Questions regarding student engagement in large-enrollment courses:

7) What do you think about student engagement in your large-enrollment course? How do you feel it works? What do you think is going on?

8) What do you think are top three teaching strategies that speak to the needs of the students?

9) You did (or did not) mention student engagement and I would like to know more about how you think you could promote student engagement in your large-enrollment course.

10) From the workshop and from reviewing the videotapes, what have you learned about your and from your students, that can help you maximize student engagement?

Questions about teaching strategies learned in the workshop

11) Let me remind you about the workshop. The main purpose of the workshop was to assist faculty of large lecture science classes in learning new ways to promote better student engagement, deepen students' learning of science, and to increase retention rates in their classes. With all due respect for your professorship, I would like you to put on the lens of a learner and tell me what you learned in the workshop that you believe you could apply in your classroom.

12) Here is a list of teaching strategies that were presented during the workshop. Did you implement any new teaching strategy during the program? In case you made changes in your teaching approaches, what was your reason for implementing them? Describe how you felt when you implemented this new approach.

13) Describe any perceived challenges when implementing a new teaching approach, such as one learned in the workshop. How do you deal with these challenges?

14) Describe any indicators suggesting how these changes were received by students.

15) In case you did not change your teaching, what was your reason for not trying something new?

Questions about students' prior knowledge (modeled after ATI items):

16) Before participating in the workshop, what was your sense of your students' prior knowledge of the subject matter?

17) Describe any consideration you gave to students' prior knowledge of the subject when designing and planning to teach this course. What do you believe contributed to your consideration?

18) What consideration (if any) did you give to testing your ideas about students' prior knowledge of the subject?

19) Describe how you incorporate students' prior knowledge in your teaching after participating in the program.

Questions about the relevance of subject taught (modeled after ATI items):

20) How do you describe the subject to your students? How do you explain to your students the importance of the material you teach?

21) Describe differences and similarities in your approaches to describing the relevance of the subject you teach before and after the program.

Questions about student-student interactions:

22) Identify aspects of your teaching design that you believe are essential to promoting student-student interaction in your large-enrollment course.

23) After reviewing the videotapes, what is your sense about student interaction in your class?

24) Identify strategies and activities that you attempted in order to promote active student interaction in your class.

Questions about course structure and pedagogy (modeled after ATI items):

25) How do you design and plan a large-enrollment course compared to a small-enrollment course?

26) Describe your course objectives. Explain your strategies for making students aware of these strategies.

27) Explain how you connect the course objectives to your teaching approaches. Give me a specific example.

28) Describe differences and similarities in your strategies to match course objectives with pedagogy before and after the workshop.

Questions about course assessment procedures (modeled after ATI items):

29) How do you design the assessments used in your course?

30) Explain how you connect your assessments with your course objectives and pedagogy. Give me a specific example.

31) Describe differences and similarities in your assessment strategies before and after the workshop.

Questions about the role of watching teaching videotapes:

32) I appreciate your allowing me to videotape your class sessions, thank you very much. Please tell me your impressions from watching your videotaped teaching sessions. How did you feel when you watched yourself teach?

33) What stood up for you when you reviewed the videotapes? Have you learned anything?

34) What can you tell me about student engagement after reviewing the videotapes?

35) Did you present the material in the way you intended to present? Was there a way you could have done or said in another format to be more engaging?

36) To what extent do you believe watching yourself teach on video influenced your thinking about your approaches to teaching?

37) Did watching yourself teach bring new information about how students react to it? Give me a specific example.

38) How would you compare your beliefs about teaching before and after analyzing your videotapes and engaging in reflection about your teaching?

Questions about the role of discussions with the researcher:

39) I would like to know your impression about our follow-up discussions and the process of implementing new strategies learned in the workshop. Give me a sense of how you felt throughout your interaction with me during our follow-up discussions. What did you find most useful for enhancing your planning and teaching?

Questions about the program:

40) Teaching a large-enrollment science course is a major challenge. Please give me your ideas on how to improve a workshop to support professors' teaching a large-enrollment course.

41) Overall, how did you perceive your teaching of this course before and after the program?

42) Please give me your thoughts about any professional development strategy that you see may lead to enhancing teaching a large-enrollment course.

43) What do you think are possible ways in which the Teaching and Learning Center may assist professors in their efforts to promote student engagement in general? Can you give me an example?

44) I have finished with my questions now. Do you have any considerations that we haven't discussed and you would like to share with me?

Thank you so much for spending your time to talk with me. Your input is going to be very valuable to the development of this project.

APPENDIX H

Research Question	Data source
1) What are participants' conceptions about teaching large science courses?	Researcher's notes from the initial informal meeting (Pre-Notes); Participants' reflection notes on teaching large classes (Reflection); Participants' statements of teaching philosophy (Philosophy); Participants' course syllabi from prior to attending the workshop (Syllabus).
2) How do participants' teaching approaches transform after engaging in reflection and dialogue on their teaching?	Transcripts of initial and final interviews (Initial Interview, Final Interview); Researcher's notes from meetings with the participants throughout the program (Post-Notes); Participants' updated resumes (Resume); Participants' course syllabi from prior to and after attending the program (Syllabus).
3) To what extent are these transformations reflected in their teaching practices?	Transcripts of video recordings of course sessions, including researcher's observation notes (Video); RTOP scores of videotaped course sessions (RTOP); Participants' course syllabi from prior to and after attending the program Syllabus); Participants' teaching artifacts (Teaching Artifact).

APPENDIX I

Category	Sub-category
Teaching approaches	
	Course organization
	Students' prior knowledge
	Assessment
	Attitude toward students
	Instructional approaches
	Perception of teacher's role
	Perceptions of teaching effectiveness
	Facilitation of class interactions
Teaching a large course - Constraints	
Teaching beliefs	
Self perception	
Teacher growth	
Engagement in SoTL	
Observed teaching behavior	
	Incorporation of active learning
Impressions about implementation of active learning	
Attitude toward transformation of teaching	
Influences of the program on teaching	
	Role of workshop
	Role of videotape watching
	Role of dialogue
Ideas about future programs	
External factors	

APPENDIX J

Adrian	
	Reflective Cycle #1
Video	Enacted teaching practices: Lecture.
Discussion	Researcher's suggestion: To implement peer instruction. Flashcards were provided to the instructor.
	Reflective Cycle #2
Video	Enacted teaching practices: Peer instruction with flashcards.
Discussion	The participant had personal ideas on how to improve the peer instruction strategy.
	Reflective Cycle #3
Video	Enacted teaching practices: Peer instruction with flashcards. Participant's ideas were incorporated to improve the implementation of peer instruction.
Discussion	Participant's misconception about the implementation of active learning was dispelled.
John	
	Reflective Cycle #1
Video	Researcher's suggestion: To implement peer instruction with clickers. Enacted teaching practices: Peer instruction with clickers.
Discussion	Participant's misconception about the implementation of active learning was dispelled. Researcher's suggestion: To include video demonstrations as interactive lecture demonstrations.
	Reflective Cycle #2
Video	Enacted teaching practices: Peer instruction with clickers.
Discussion	Researcher's suggestion: To hide the frequency distribution of students' first clicked answer to increase their curiosity and class participation.
	Reflective Cycle #3
Video	Enacted teaching practices: Peer instruction with clickers, interactive lecture demonstrations with videos, first clicked answers blocked for students.
Discussion	The participant had the personal idea on implementing JiTT with peer instruction and clickers.
	Reflective Cycle #4
Video	Enacted teaching practices: JiTT combined with peer instruction and clickers, first clicked answers blocked for students.
Discussion	Participant's misconception about the implementation of active learning was dispelled. He was enthusiastic for having been able to stimulate active student participation.

Siobhan	
	Reflective Cycle #1
Video	Enacted teaching practices: Peer instruction with flashcards.
Discussion	Researcher's suggestion: To include video demonstrations as interactive lecture demonstrations.
	Reflective Cycle #2
Video	Enacted teaching practices: Peer instruction with flashcards.
Discussion	The researcher shared video demonstrations with the instructor.
	Reflective Cycle #3
Video	Enacted teaching practices: Peer instruction with flashcards.
Discussion	No engagement in dialogue.
	Reflective Cycle #4
Video	Enacted teaching practices: Interactive lecture demonstrations, the video demonstrations provided by the researcher were incorporated.
Discussion	The participant was satisfied with her teaching.

VITA

Ioana Alexandra Badara was born in Constanta, Romania on March 22, 1970. Her father was a general surgeon who also held a PhD degree in Medical Sciences, and her mother was a school nurse. Her parents were dedicated to supporting her education, both in formal schooling and through enriching extra-curricular experiences. Ioana's interests from an early age were mathematics, science, and universal literature. By the time she graduated from high school, she was well prepared for college. Intending to become a Chemical Engineer and work in the cosmetics industry, she was admitted into The Poytechnical School in Bucharest, Romania. However, after studying Organic Chemistry for two years, she realized that her true interests were in Biochemistry and that her career belonged in a life sciences laboratory. Hence, she transferred to Bucharest University from which she graduated in 1995 with a Bachelor of Science degree in Biochemistry. After working as a research assistant in a clinical research laboratory affiliated with "Carol Davila" School of Medicine in Bucharest, she was awarded a full scholarship for graduate studies in microbiology and immunology at University of Edinburgh, in Scotland. She started on her scholarship in January 1998 and in April 2000 she moved to New York City to join her husband who was a medical resident at the time. After graduating from University of Edinburgh with a Master of Philosophy degree in 2002, she worked in bio-medical research at Mt. Sinai School of Medicine and Weill Medical College of Cornell University in New York City. Her son, John Paul, was born on January 6, 2004. Soon thereafter, her family moved to Tennessee, where Ioana decided to pursue graduate studies in Science Education at University of Tennessee. In August 2007, Ioana was appointed Assistant Professor of Biology at Lincoln Memorial University in Harrogate, TN where she worked until May 2010, when her family relocated to the Northeast. Ioana currently lives in Connecticut with her son, John Paul, and husband, Dr. Mircea Badara.